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ABSTRACT

Lagging productivity and increased competitiveness from abroad are forcing U.S. management companies to adopt new management styles that promote efficiency and quality in production. High on the agenda is the incorporation of Statistical Process Control (SPC). SPC requires definition of process and product specifications to facilitate their measurement and construction of an SPC chart to view process behavior. A Quality/Productivity Training Partnership was established in June 1986 to create a network of teams to bring the quality/productivity/SPC issue to the attention of local industry in Arkansas and provide an educational resource. In January 1987, a vocational educator representing the partnership began an internship at Borg Warner (in Blytheville, Arkansas), which was using SPC in a nurturing atmosphere created by management. Random observations and a more analytic approach involving flowcharting and cause and effect analyses were done of the manufacturing and support technologies. A mini-internship at Monroe Automotive followed. The intern then attended an SPC workshop and developed an outline for a Transformation of American Industry (TAI) program. Involvement in the internship led to recommendations for the educational process and curriculum development. (The TAI program outline is appended.) (YLB)

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FINAL REPORT

FACULTY RETURN TO INDUSTRY

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"Internship Report: Faculty Return to Industry"
(David R. Hulse)

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"Internship Report: Faculty Return to Industry"

(David R. Hulse)

I. Preface, Acknowledgements and Disclaimers

I must admit from the outset, this report has not been easy to write. I find it difficult to comment on issues I do not completely understand. However, I must cease contemplation and begin. This report must be written, and the subject defies encirclement in the time remaining. I do not expect to say anything of importance, that hasn't already been said by someone else in a much better fashion. To a large extent this report will detail how and what I have learned about Statistical Process Control and Quality Management, and how that experience has affected me.

The minute you begin to seriously consider the principles of Statistical Process Control, new perspectives begin to develop. SPC tends to reveal what is important and expose what is not. When successfully applied, it can disperse the mystery from any process, using ideas that are simple and straight forward. Dissipation of the mists generated by complexity allows for a reordering of priorities derived from conditions based in fact, not assumption and conjecture. The resulting reordering process does not happen all at once, but tends to gain momentum over time. It has begun to provide me with a backdrop that establishes relationships between previously unrelated areas of interest

and concern. It has helped establish a continuity of pragmatic philosophies that allows for examination of a wide variety of human activities with a clearer understanding. Specifically it is providing a new vantage point for evaluating the effectiveness of learning processes. It is changing my approach to curriculum development, teaching, student evaluation and program improvement. In the midst of complexity, SPC can provide a clear focus for evaluating process performance. If you really want to know, it will describe to a close approximation what the actual conditions are and characterize the effect of any changes made on the system or process.

I have never written a report like this. I don't know what others might expect. These are important matters. I hope no one takes my approach too seriously. I do not wish to be misunderstood. In a conversation that took place after the internship was over, I was asked "how it had gone". I smiled and said, "I had a wonderful time". I was then informed that I had not been returned to industry for my personal enjoyment. I was stunned. I didn't know whether this person was serious or not. Upon reflection I conclude that they were. This incident points indirectly to the adversarial relationship that exists between management and labor in many work places today. In its most negative form the worker's first motivation is to do as little as they must for as much compensation as possible. Management in its turn views the worker as a resource to be exploited.

Relationships based on such negative dynamics must be changed. In the absence of trust, common objectives and mutual understanding everyone assumes the worst. Since noone really enjoys their job, "having a wonderful time" means neglecting your responsiblities. As the person turned and walked away I replied, "I'm sorry. I didn't have any choice".

It's true. Every morning, I looked forward to walking through those plant doors. I would walk across the plant floor saying hello and good morning to whomever I met. Violet Kelly was always there with a smile and a warm greeting. I would make my way to my desk, grab a cup of coffee, begin assembling my notes and wait for things to start happening. I never had to wait long. It was an uplifting experience and a fascinating adventure. The atmosphere was such that just being "there" made me feel better. I need to thank everyone at Borg Warner, but Rita Bell and Charlie Holoway in particular. Also, special thanks to Kay Shrieve and the plant manager of Monroe Automotive. Of course none of this would have happened without Bill Cromer.

I've decided that what is important concerning this report, is that I'm honest, and try to communicate what seems significant. That's what I have done. After reading it, you may conclude that it's idealistic. I would not argue with you. I would like to point out that as this report

indicates, there some people in Blytheville Arkansas busy making the ideal a reality.

Introduction

II. Importance and Relevance of Statistical Process Control.

The concept of the "Post Industrial Economy" was first envisioned in the late 1950's by Dr. Daniel Bell. It is based on the premise that developing technologies enable the mechanization and automation of the manufacturing sector of the economy. This provides for a natural evolution of the work force away from labor intensive jobs. Fewer people would be required to produce the same amount of "Goods and Services". Boring, repetitive tasks would be eliminated. People would be allowed to realize more of their potential in less strenuous, more human activities.

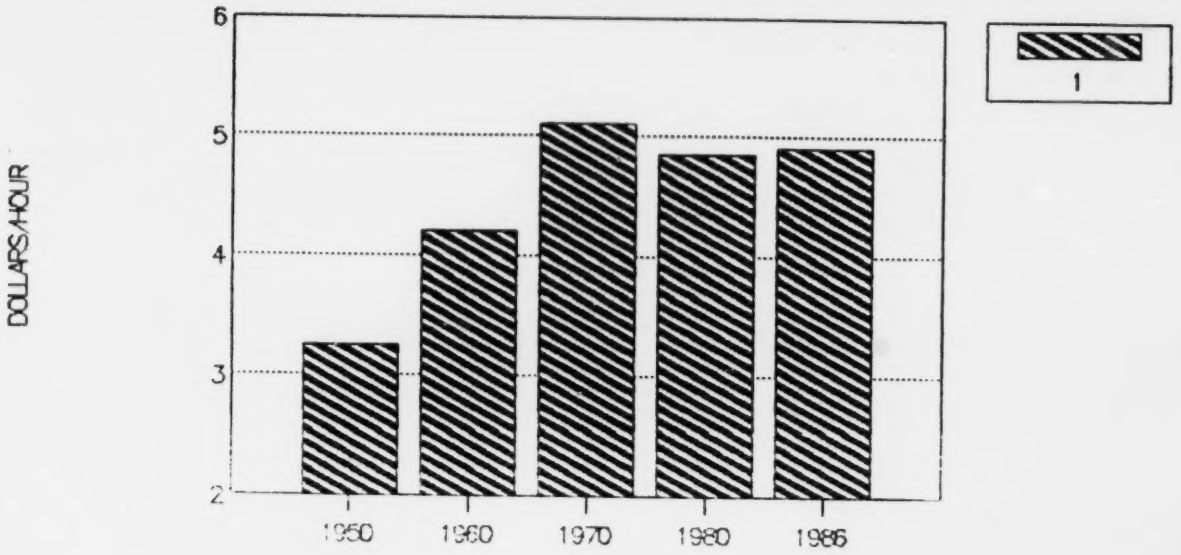
Statistics indicating a shrinking percentage of the work force engaged by industry and an expanding service sector have been interpreted by some to be a sign that we are indeed progressing toward this desirable state. However, this change in the economy, that has been occurring since the early 1970's, is not the positive development toward the "Post Industrial Economy", but a negative trend toward "The De-Industrialization of America". This trend has its roots, to a large extent, in our inability to compete in world markets. Hundreds of manufacturing companies have gone out of business, thousands of plants have closed, millions of jobs have been lost. The trade deficit is currently running between 10 and 15 billion dollars per month. At an estimated 25,000 jobs per billion dollars, this translates into about 300,000 jobs lost in December of last year. Most

of these were in manufacturing, which is the most potent component of the engine driving our economy. One dollar spent in manufacturing produces $1.34 of additional domestic spending. One dollar spent in the service sector produces only $.72. As manufacturing goes, so goes the rest of the economy.

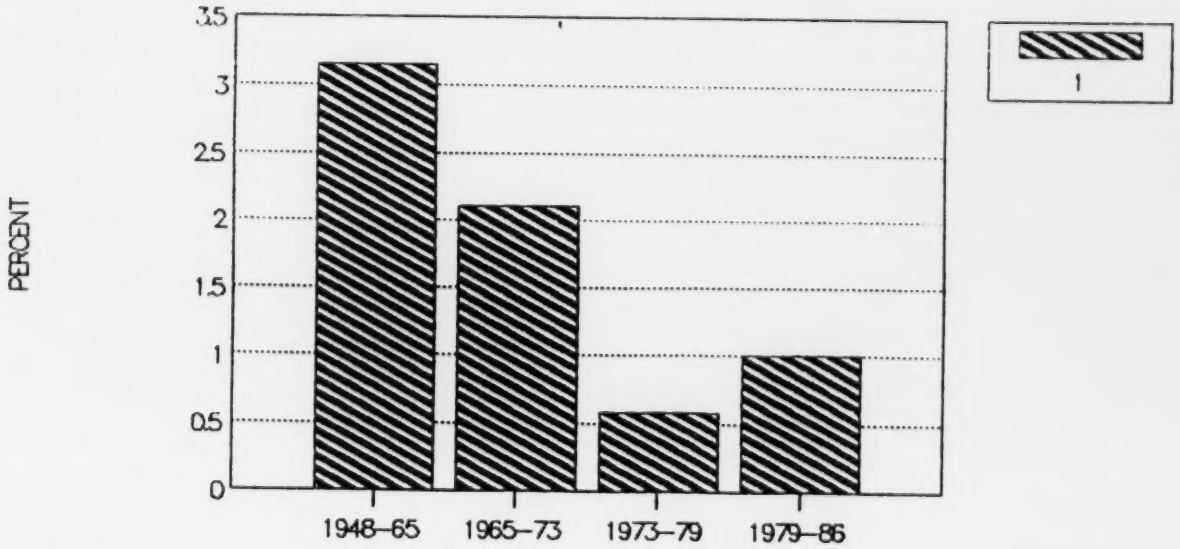
The primary culprit is lagging productivity. Growth in output per hour had declined from 3.1% in the 1960s to .6% by the mid 1970s. When gauging the performance of competitors in the world economy in terms of growth in output per worker, America's 1% earns it a position at the bottom of the heap. This translates into a declining standard of living. The average hourly wage had decreased to just under $5.00 per hour in 1986. We have maintained an economic status quo through entry of more people into the work place. In the 1960s 39% of the population participated in the generation of income. By 1986 this had risen to 46%. Income has not risen by a like amount. In summary. Lagging productivity causes declining competitiveness. Inability to compete leads to loss of market share. Manufacturing plants close, jobs are lost and economic conditions for everyone worsen. As has been pointed out, this is the first time in America's history that our children will enjoy a standard of living less than that of their parents.

This increased competitiveness from abroad is forcing American management to reevaluate its way of doing business. Many companies are adopting new management styles that

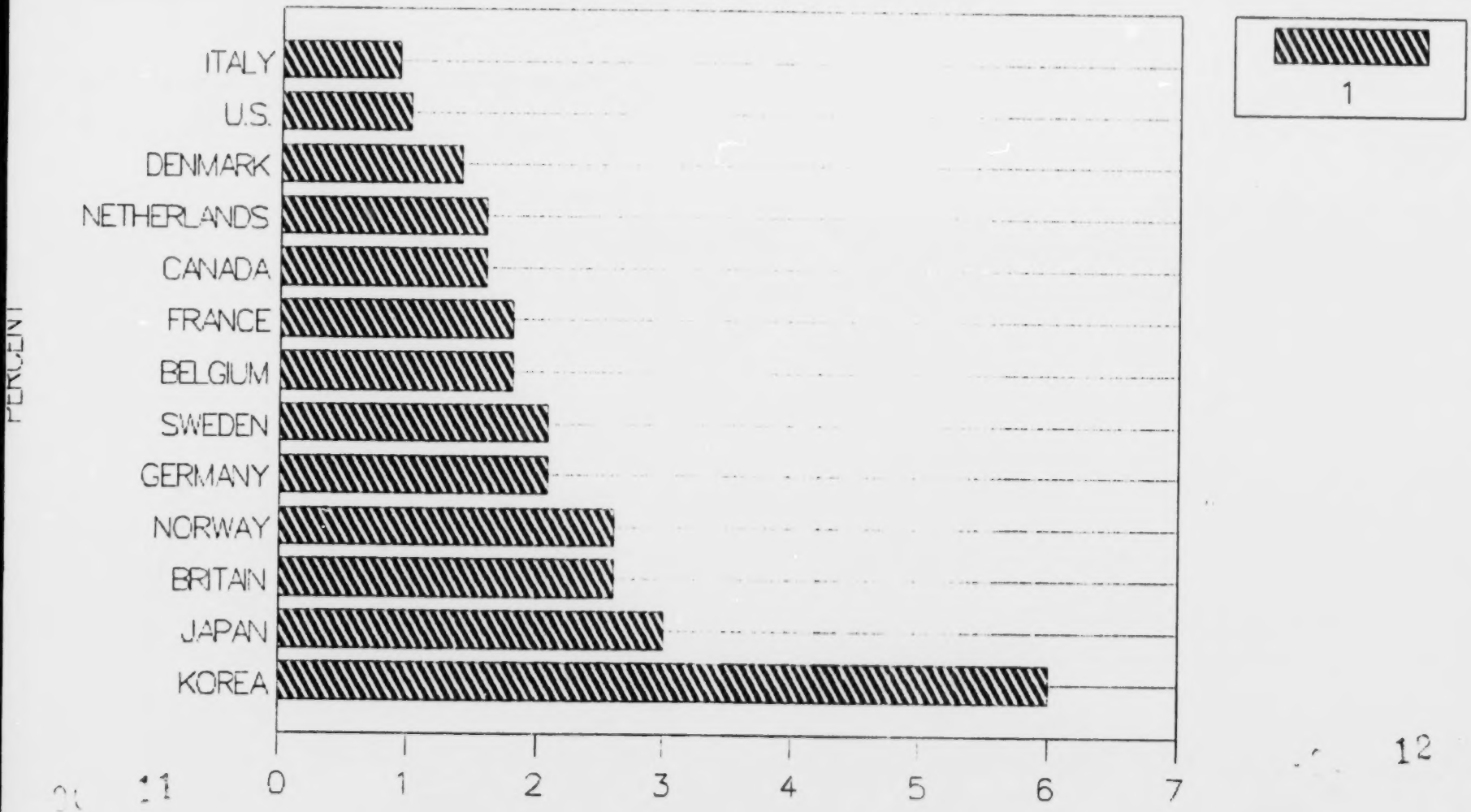
AVERAGE HOURLY EARNINGS IN 1977 DOLLARS



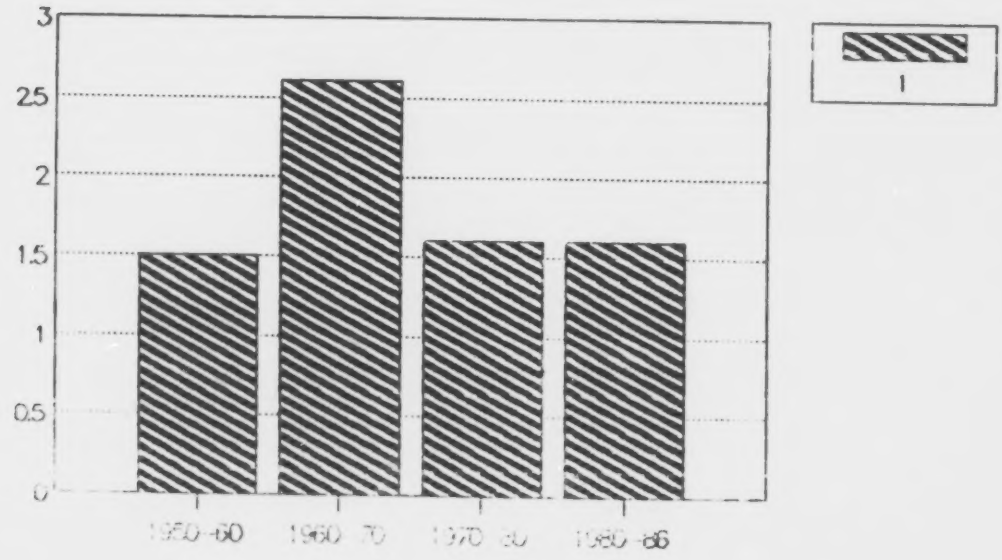
AVERAGE ANNUAL GROWTH IN OUTPUT PER HOUR



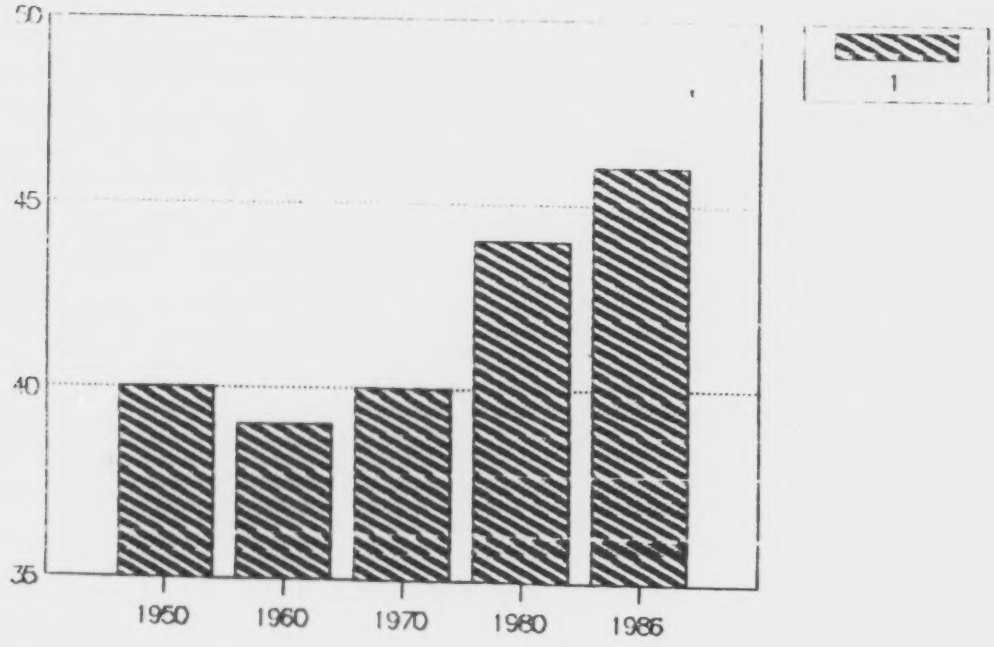
GROWTH IN OUTPUT PER WORKER



PERCENT CHANGE IN REAL DOMESTIC PRODUCT PER PERSON



RATIO OF EMPLOYMENT TO POPULATION



promote efficiency and quality in production. These have in common, an effort to understand current manufacturing processes well enough to approach a "Zero Defect" quality standard. It has been demonstrated that the easiest way to increase productivity is to find ways of doing the job right the first time. To achieve this, several steps are required. 1. A company must foster a sense of common purpose and cooperation between management and labor. 2. Statistical methods that accurately describe the performance of the manufacturing process must be utilized to provide a base line for continuous improvement. 3. New technologies must be incorporated to increase efficiency. 4. Human resources must be maximized through training and education. In response to the seriousness of the situation, "Quality Initiatives" have started popping up all over the American manufacturing and educational scenes. Concerned individuals are trying to do something before it's too late. High on everyone's agenda is the incorporation of Statistical Process Control (SPC) into manufacturing processes. A consensus is being reached. Quality needs to be controlled through a prevention, rather than a detection model. That is, the manufacturing process should be managed in such a way as to prevent defects before they occur, rather than sorting good parts from bad. It is also being recognized, that SPC flourishes in a specific kind of environment. Management is faced with finding new ways of conducting itself; of creating a "Quality Culture". This project is an

outcome of one of these quality initiatives and seeks understanding of these two main ideas.

III. SPC: An Overview

The concepts and techniques forming the foundation of modern SPC were established by Dr. Shewhart at Bell Telephone Laboratories in the 1920's. These ideas were presented to American Industry during World War II by Dr. W. Edwards Deming, in an effort to bring about higher productivity for the war effort. Although well presented to a wide audience, the initial impact was blunted and dissipated by upper level management's unwillingness to participate in the changes indicated by this new source of information. By the early 1950s SPC as a management tool had disappeared from the American manufacturing scene.

In 1949 Dr. Deming began teaching statistical methods to Japanese Industry. With the help of Mr. Ishikawa the importance of applying statistical methods to manufacturing processes was made plain to "Top Management". The end result has been a developing commitment, during the last thirty years, toward "Total Quality Control" as the overriding philosophy affecting Japan's approach to manufacturing. What began as a simple emphasis on defect prevention has grown to include:

1. A philosophy of continuous improvement emphasizing prevention.
2. Responsibility for process performance in the hands of the production worker.
3. Comprehensive application of quality control in all processes.

4. Quality standards and measures that are visible and easily understood.

5. Just In Time Inventory Control.

6. Development of automated measuring and feedback control systems.

7. Supplier qualification.

The above characterize an approach to manufacturing that has evolved to world dominance over the last thirty years. American industry began to realize its difficulty toward the end of the last decade. Among the first to begin coming to grips with increased foreign competition was FORD Motor Co. It began with an adaptation of Dr. Deming's methods of Statistical Process Control and an initiative towards constructive employee involvement. Eight years later Ford has risen to the top of the American Automotive Industry and is beginning to hold its own with Japanese auto-manufacturers.

To achieve these results, FORD not only had to make internal changes, but had to require the same from its suppliers. You can't build a quality product if you are being supplied with bad materials. FORD asked that SPC be used by its suppliers as a way of being assured that purchased materials were free from defects. Further more, FORD asked that statistical evidence be provided, showing that all processes were in control and capable. This had the effect of turning the Original Equipment Manufacturers (OEM) upside down. Those who were unwilling or not able to comply lost their

contracts and went out of business. One of the companies that was successful in making the transition was Borg Warner. They became a Q-1 supplier to FORD early on. They were successful because they began early and exercised unwavering commitment. Commitment in the light of right understanding, at the highest level of management, is the prime ingredient for success.

The path that leads to establishment of a true quality culture may begin by doing what needs to be done to insure survival; the incorporation of SPC for example. However, when certain point is reached, the source of motivation changes. Quality improvement is a consciousness raising activity. Values change. Thinking processes change. Proper perspectives emerge. The process begins to nurture itself. The reservoir of energy and resources available to get the job done, becomes focusable in more efficient and effective ways. The result is a more competitive footing for the company. Adoption of SPC and a management style that allows it to flourish is necessary for those companies who expect to survive in the new "World Economy". It is imperative that everyone associated with manufacturing, from the production worker to the president of the company, have a working knowledge of this important production/management tool.

IV. SPC Fundamentals

A. Variation, Statistics and the Manufacturing Process

The techniques of statistical control may be applied to any repetitive process. A process is any predetermined sequence of events or system of causes designed to give results that meet a desired criteria. Philip Crosby's working definition of Quality is simply "Conformance to Requirements". A quality process then, is one that produces a product or result that meets the required specifications. For improvement to take place it is clear that process and product specifications must be defined in a way that enables them to be measured and evaluated. In manufacturing these definitions are almost always in terms of some physical characteristic that may be counted or described by some direct or indirect measurement. These "Designated Characteristics" are described by criteria related to the product's ability to do the job for which is was designed and are the primary focus of data gathering for statistical analysis. The purpose of this analysis is to detect process trends that tend away from its normal character or distribution. If these trends are detected early enough, proper corrective action on the process can prevent production of parts that do not meet requirements. This reduction of scrap increases productivity, and makes the company more competitive.

The results of all repetitive processes are subject to variation. Variation is due to fluctuations in the

materials, systems and procedures that define the process. There are two distinct kinds of variation. Random causes stem from minute differences in process inputs over time. These differences are always well within current operating parameters. The resulting natural variation determines the character of the population produced. This is called the distribution of the process and closely follows one of several statistical laws that describes the theoretical limits of the population. As long as the process operates within these limits in a random fashion it is said to be in control.

An "Assignable Cause" is a disturbance in the process that produces non-random variation, or produces results that are outside the natural limits of the process. If assignable causes are present, the process is not in control, and production of scrap is currently taking place or soon will be taking place. Evidence that assignable causes are affecting a process can be obtained from the analysis of statistical data. Once detected, the nature of the cause must be understood to determine the corrective action necessary for its removal. If removed in time, no scrap need be produced.

One of the reasons for the success of SPC in manufacturing stems from the simplicity with which the mechanics of its techniques can be implemented. It can become an effective tool in the hands of the production worker. Control of the process in the hands of personnel with most immediate

contact minimizes reaction time to process problems. SPC, used properly, becomes a light shining in a dark place, enabling early detection and corrective action.

B. Charting Techniques.

There are two categories of SPC charts. Variables charts are used for formatting data that is the direct result of a measurement. This will be some rational number. The most common of these charts is the X bar and R. The Attribute chart is used to format data that is generally the result of some counting operation. This will be some integer. There are four commonly used attribute charts: the P, the nP, the U, and the C. All of these could be found on the shop floor in the hands of the operator.

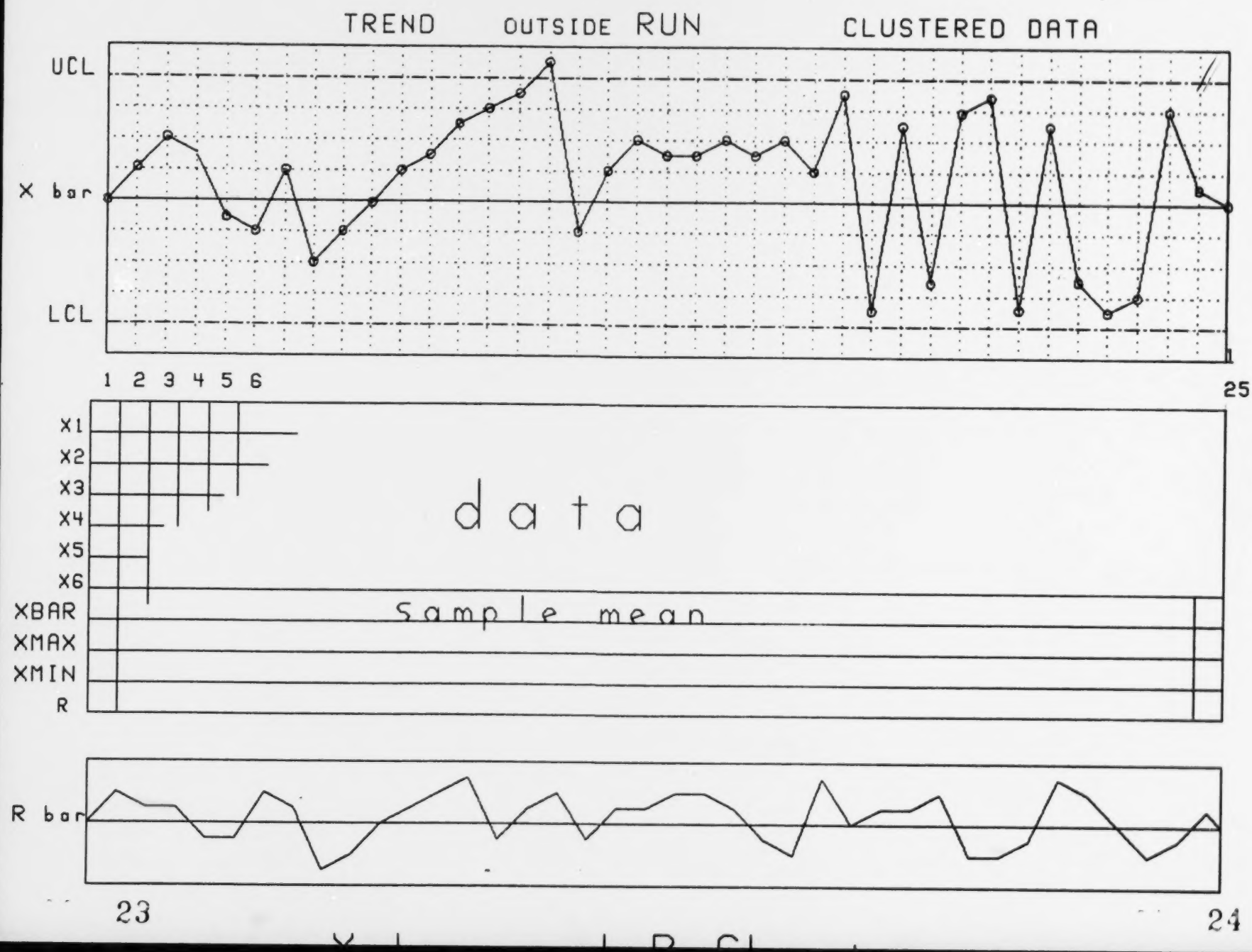
The construction of the these charts varies only slightly, so the X bar and R will be used to illustrate the basic procedure. See the figure. A sampling rate is the first thing that needs to be determined. How many parts are going to be examined, how often? This something to be determined by the QC engineer or SPC specialist. For example, a process may be sampled at a rate of five parts per hour. After a minimum of 25 samples have been taken, construction of the chart can begin. First, the average of each sample is calculated. This is the quotient of the sum of the elements in the sample and the number of elements in the sample. It is called X bar. Next the range of the sample is determined. This is the difference between the highest and lowest value in the sample and is called R. This done

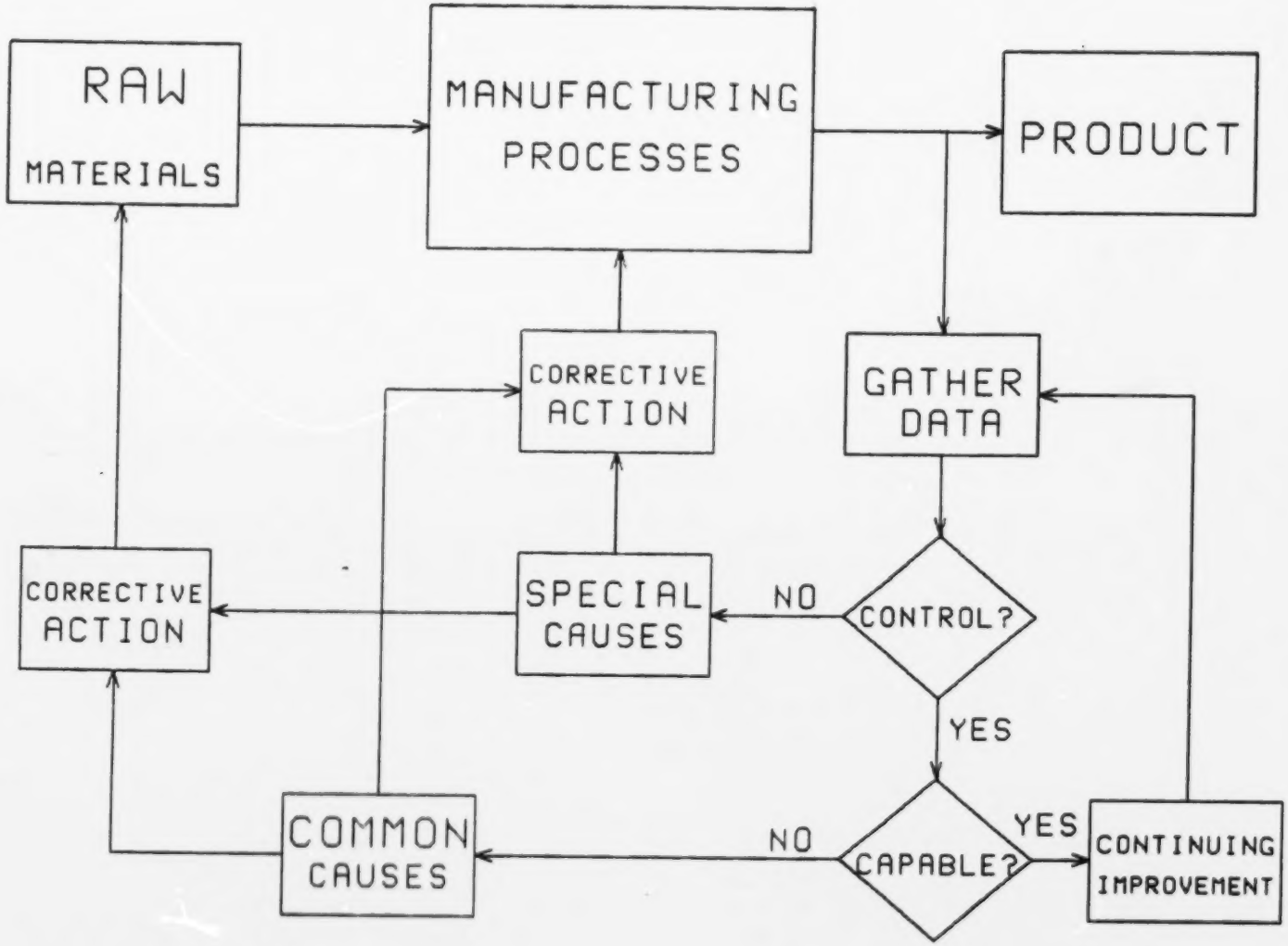
for all 25 samples. Once completed the averages of X bar and R for the 25 samples is determined. This information is then formatted graphically on the chart. Next the upper (UCL) and lower (LCL) control limits are calculated and placed on the chart. UCL is determined by taking the sum of the product of the appropriate statistical constant and the range average, and the process mean. LCL is determined by taking the difference between the product of the same constant and range, and the process mean. This last action completes the chart. For every sample period new information in terms of Xbar and R values is added to the chart.

C. Data Analysis and Corrective Action.

Once the chart is operational it can be used to view process behavior. Out of control conditions are signs that assignable causes are present. These conditions can be characterized in the following ways.

1. Data points beyond the upper and lower control limits.
2. A run of seven data points above or below the process mean.
3. Trends of seven consecutive data points progressively increasing or decreasing in value.
4. Nonrandom behavior; e.i. clustering of data points in ways that are not consistent with normal distribution.


TREND
OUTSIDE RUN
CLUSTERED DATA
UCL
X bar
LCL
1 2 3 4 5 6
25
X1
X2
X3
X4
X5
X6
data
XBAR
XMAX
XMIN
R
Sample mean
R bar
23
24



S.P.C. CONTROL LOOP

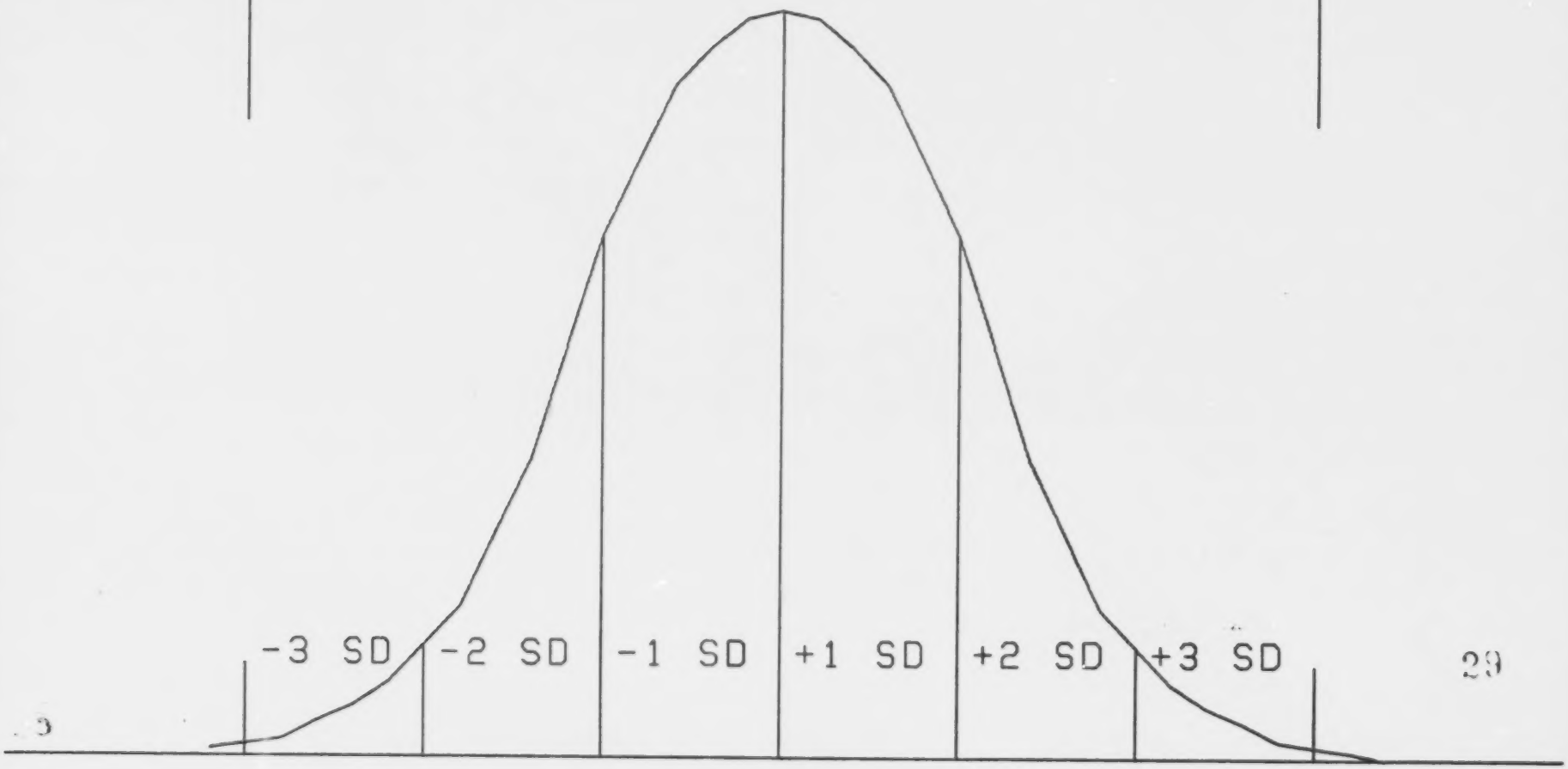
As the operator updates his chart he examines the past record for out of control conditions. If detected, the cause must be determined and appropriate corrective action taken. It should be noted that out of control does not mean out of specification. Because the process is beginning to behave in an unpredictable manner does not mean that bad parts have been produced. This is the strength of SPC. It allows problems to be corrected before they do any damage.

D. Process Capability and Process Improvement.

Once a process is in control, "process capability" may be determined. This is done by comparing the mean and extent of the process's distribution with the upper and lower specification limits of the feature. The extent or spread of a distribution can be indicated by a number called sigma (σ). Sigma is used to represent the standard deviation of the process and is the square root of the variance. The variance is an indication of the magnitude of variation in the process. It is determined by taking the quotient of the summation of the squares of the sample average (Xbar) and the process mean (Xbarbar) differences, and the number of samples considered (n) minus one.

Once the standard deviation of the process is calculated, you can determine how many "σs" there are between the process mean and the upper and lower specification limits. In this way it becomes possible to mathematically predict the number of parts per thousand or parts per million, that will be produced outside specifications. For example, if

SPECIFICATION LIMITS FOR A 3 SIGMA PROCESS



NORMAL DISTRIBUTION

there are three standard deviations between the process mean and the upper specification limit and the lower specification limit (a 3σ process), on the average 2.7 bad parts will be generated for every 1000 parts produced. A 4σ process will generate 63.4 bad parts per 1,000,000 parts produced. These are true statement only if the process is in control. That is, there are no assignable causes present. At this point in time American industry is thinking in terms of 3σ. The Japanese are thinking 4σ. Process improvement means increasing process capability. Modifications must be made so that 3σ processes becomes 4σ processes.

E. The Future of SPC.

There is more to SPC than technique. SPC becomes a way of thinking. Data collection and analysis underlie the decision making process. "Get the facts. Figure out what they mean. Then choose a course of action". Those who think this way have a definite advantage over those who don't. Survival in today's marketplace means capitalizing on every advantage available. Dr. Deming maintains, that companies attempting to compete in World Markets not using SPC will not survive. In some respects "SPC is the future".

F. Technology

The impact of new technology will dramatically effect the way SPC is implemented in the modern manufacturing plant. This major impact will be due to development in two areas. The first is the use of the computer to collect and process

data, and to control the operation of automated manufacturing systems. The second is the development of new sensors and transducers and measurement systems capable of responding accurately to changes in variables that previously required the attention of a human being. SPC is nothing more than a closed loop control system that deals with fuzzy data and information. The day is quickly arriving where measurements will be made, data will be processed and corrective action taken without the intervention of human hands.

V. Chronology of Events Leading Up to The Return to Industry

This report is about more than SPC, Quality Improvement and the internship. In it, I am trying to understand what my role should be. From my vantage point, there is an large amount of work that could and should be done. On my cynical days, I find myself uttering the maxim: "Those who are willing to do more - do more. And those who are willing to do less - let them." It is really no one's fault but mine. I need to get control over my enthusiasm for starting new projects and finish a few. In this report I am sifting priorities, trying to answer the question; "What can I expect to accomplish without becoming spread too thin?" The following is for perspective; to make understandable the conclusions I am beginning to reach.

A. The Fairfield Bay Project: "Transformation of American Industry"

On May 9, 1986 I was accepted as a participant in the Quality/Productivity Training Partnership that was conducted at Fairfield Bay during the first week in June of that year. At the time I had no idea how this event would affect the way I think about Vocational Education and its relationship to the customers it serves; ie. the student, business and industry. On the first day, during a portion of the program called "Marketing Quality", the presenter remarked that in every group such as our's, there are a few whose introduction to SPC and Quality Management becomes something akin to a religious experience. Such has proven to be the case with me. As with anyone who first glimpses a truth and

becomes determined to pursue it, I have gone through several stages of development and changes in attitude over the last two years. These are reflected in this report.

Concerning the workshop itself, it was by far the best conceived, planned and executed program of its kind that I have attended. Its primary purpose was to create a network of teams, functioning around the state to bring the Quality/Productivity/SPC issue to the attention of local industry; and then to provide an educational resource enabling the first stages of involvement with SPC. Each team was organized with three members; a Quality Professional, an Industrial Coordinator and an Educator. The American Society for Quality Control (ASQC) provided a base for selecting the quality professionals. They were generally individuals working as quality control engineers or specialists for various companies around the state. The industrial coordinators were state employees, whose responsibility it is, to assist Arkansas companies in establishing training programs for their workforce. The educators were principally State VoTech mathematics instructors. Each team was selected so that it could function in a specific region of the State. The industrial coordinator was to open a dialog concerning Quality and SPC with the companies he served. SPC training programs were then to be conducted by the VoTech instructor. The quality professional was to provide assistance in the classroom and

support in implementing SPC on the shop floor. All in all, a well thought out plan.

The first obstacle in achieving this goal was that the participants, once selected, had to be sold on the idea and then trained. That is what happened at Fairfield Bay. The following is a synopsis of the program.

1. Marketing Quality

In describing how the Quality issue should be presented and sold to business and industry, the speakers sold the same to their audience. I found their presentation clean and effective. Their arguments were incontrovertible. It was at this point in the program I began to become a "Believer". They began by contrasting the way manufacturing is currently done (for the most part) with the way it should be done. Rather than scavenging the output of a process to separate the "good" from the "bad", the process itself should be managed in way that continually reduces the amount of scrap produced. They suggested ways of getting upper level managements attention. One of managements primary goals is maximization of profit. Thus the question; "How can the product be made better, faster and more efficiently?" The answer is Quality Improvement. They also pointed out that changes in attitudes toward Quality had to begin at the top of the company hierarchy. Once commitment was established there, it would eventually permeate the whole organization. From their experience the major obstacles to program adoption were listed as:

1. Upper level managements misunderstanding of the quality improvement process.

2. Deficiency of basic skills in the work force.

3. Poor communication between management and labor.

Solutions for these problems had been incorporated in the "Transformation of American Industry" program and would over time radically change the companies way of doing business for the better. Other solutions related to the basic skills question were to be found in additional training and education programs such as basic math and blueprint reading.

2. The Transformation of American Industry

The Transformation of American Industry Quality/Productivity Improvement Program is designed to allow for the incorporation of statistical process control in plant operations, and for the initial development of the quality culture necessary for its support. This is accomplished in two parts. First, in the establishment (in the classroom) of Quality/Productivity Improvement Teams. Second, in the training of the teams in the use of statistical methods and problem solving techniques as applied to manufacturing. The Transformation of American Industry program is multidimensional in its approach. Recognizing that Statistical Process Control must have a supporting environment in which to flourish, it attempts to create that environment on a small scale in the Quality Improvement Team. Some of the characteristics to be achieved are as follows:

1. Increased vertical communications. The Q/P Team provides a time and place for employees from different departments to share experiences and information concerning company operations.

2. Increased employee involvement. The Q/P Team provides a framework for the participation of employees from different departments in the establishment and achievement of common goals and objectives.

3. Concentration of resources towards a desired end. The Q/P Team facilitates efficient realization of process improvement goals by focusing the required knowledge, skill, responsibility and authority on a specific aspect of company operations.

4. Positive effect on Company Culture. An increased awareness on the part of the participants of their relationship to the overall goals of the company. Identification and elimination of impediments to the quality and productivity improvement process. Teamwork is established.

The Q/P Team should be made up of a cross section of plant personnel that will facilitate the implementation of the Deming Cycle.

1. Project selection
2. Project implementation
3. Project evaluation
4. Development of strategies for continuing improvement.

Once a team has been formed and a project selected, SPC techniques are presented and applied. The principle teaching method used is the application of information, concepts and techniques to an actual in plant situations. Therefore, a real and measurable result is present at the conclusion of the program. Successful completion of the Deming Cycle should provide a pattern for continued and expanded improvement throughout the plant.

3. The "Question"

I believe it was Thursday, midmorning. We had been having a crash course in SPC for the last three days. One of the project coordinators stood up and addressed the following question to the vocational instructors in the group. "Are you going to be ready to teach SPC after you get finished here?" We all gasped. Although widely distributed in the audience, we came to a consensus quickly. We agreed that the mathematical methods were well within our abilities to present in the classroom. What worried us was our total lack of experience in the application and use of these ideas in the real world. A representative from industry suggested that it would be useful for potential instructors to work in a manufacturing plant using SPC. Everyone agreed that this was a good idea.

B. The visit to Francis Tuttle

In the spring of 1986 a group from the State Department of Vocational Education and the University of Arkansas Fayetteville visited Francis Tuttle Vocational Center in

Oklahoma City. Our purpose was to examine the use of "Unified Technical Concepts" (CORD) in a vocational training environment. (As a result of this inquiry, UTC is currently being used as a complement to technical training at four vocational schools in Arkansas.) During this visit, I became interested in the approach taken at Francis Tuttle to curriculum develop, its implementation, and the relationship that had been established with local industry. In July I returned for two days to take a closer examination.

Although in operation for less than two years, the four programs of interest to me, showed more maturity than expected. These were the Industrial Instrumentation, Computer Maintenance, Electro-mechanical and Electronics Programs. All were developed along the lines of open entry-open exit, selfpaced, individualized instruction. The basic building block of curriculum implementation was the Learning Activity Package (LAP) which directed the student's training by defining specific goals and objectives and then referring the student to pertinent texts, audio/visual materials, laboratory exercises and evaluators. Thus the student was made semi-independent of the instructor, could begin the program at anytime, move at his own pace and even set his own work schedule.

How was this achieved in such a short time? The leadership made the decision and then the staff followed through by working long hours, including weekends, until the job was completed. The result is impressive. The student becomes

more of an active participant in the learning process by taking responsibility for his education. The instructor has more free time for program improvement and curriculum development. Flexible entry and exit points and scheduling allow individuals to participate, who under other circumstances would not be able to do so. The only concern that assailed me during my visit was effect of the diminished student-teacher dialog. This remains an unanswered question.

The degree of involvement between local industry and Francis Tuttle was even more impressive. Because of the competency of the staff and the organization of the department, important services could be offered on a fee basis. At that time these primarily consisted of in plant, job task analysis and training program design and implementation. Thus local industry used the school's capabilities as a training-retraining resource for its employees. This provided an additional source of income for the school, but more importantly, it solidified a working relationship with industry. Needless to say such circumstances facilitate placement of graduating students.

Experiences at Fairfield Bay had motivated me toward a deeper concern for the relationship between industry and vocational education. What I saw at Francis Tuttle widened my horizons concerning what was possible. It was time to start doing things.

C. The ASQC Meeting

In September of 1986 following an inclination generated by the Fairfield Bay and Francis Tuttle experiences, I invited myself to an American Society for Quality Control (ASQC) meeting. Due to a misunderstanding, I ended up barging into a meeting of the State Steering Committee. They made me welcome and allowed me to witness the proceedings. One of the primary concerns being discussed was getting out the Quality/Productivity/SPC "MESSAGE" to industries around the state. They were in the early stages of planning Arkansas's first quality conference. I was well impressed with the level of professionalism demonstrated.

Jan Partain from AIDC and Dr. Norm Park from VOCED were present. During the course of the meeting I had a chance to explain that I was searching for ways to develop a closer relationship between State supported technical education and professional organizations such as ISA, IEEE, SME and ASQC. Knowing that these organizations have an active interest in keeping there memberships up to date with current technology through publications, training materials and seminars, they represent a relatively undeveloped resource for post secondary technical education. I expressed an interest in developing an SPC delivery system for the classroom, as well as for local industry as a follow through to the Fairfield Bay project. The issue of practical experience in industry for the curriculum developer/instructor was met with a suggestion for an internship to take place with a company with SPC well integrated into their ways of doing business.

Dr. Park indicated that grant moneys were available and suggested that I apply. I did. It was approved.
The goals and objectives of the internship were stated as follows.

1. Provide industry experience for SPC/TIA training staff in quality control departments.
2. Develop and implement an SPC/TIA training program.
3. Support local industry in the use of SPC in its quality control departments.
4. Provide a closer link between local industry and state supported vocational education by becoming more responsive to in plant training needs.

D. Growing involvement with Industry

1. In Plant Training: Industrial Electricity

Fairfield Bay and Francis Tuttle had made me more sensitive to the role Vocational Education should be playing with respect to industry and business in meeting their training needs. The industrial coordinator had been asking for assistance in providing in plant training programs and I had always responded that the electronics department at Pulaski VoTech more than accounted for my free time. (Which is true) Inserting some new and reordering some old priorities, made me respond differently when given the opportunity to put together a program in industrial electricity for a small local company. This was a cooperative effort with Donnie Gundolf, the Industrial Equipment Technology instructor. We met with a

representative from management and the maintenance supervisor and discussed the problems, analyzed job requirements, developed appropriate goals and objectives and then designed a training program to meet them. We felt very good about results of our efforts. Only one disturbing question remained. Who would make it work? Who would teach the course? Neither my nor Donnie's schedule permitted the time required. The industrial coordinator said that he would find someone that was qualified. This made us nervous since we had no way of knoving how the program would be delivered. A course outline is not detailed enough to insure realization of educational goals and objectives. Donnie and I knew something more detailed was needed, something similar to the learning activity packages I had seen at Francis Tuttle.

2. The Electronics Training Program for Midlevel Management.

Because of the positive nature of test validation in the field of electronics technology, (Pulaski VoTech finished significantly higher than any other school in a five state area) a company asked the electronics department to put together a basic training program for midlevel management personnel. Seeing this as am opportunity to get involved, I agreed to write and teach the program. The twenty participants attended three days a week from 3:00 to 6:00 PM for sixteen weeks. At its conclusion, just before Christmas, they evaluated the program. The results encouraged management to repeat the process in the late

winter and spring of 1987, this time for 19 weeks. Since I would be on intearnshp at that time, Donnie Gundolf took charge. The results were as equally positive. This was the beginning of an important relationship.

3. Education Chairman for ISA

In the summer of 1986, the executive committee for the Central Arkansas Section of the Instrument Society of America, asked me to serve as education chairman for the 86-87 year. Here was another chance to get involved. I agreed. The major project for the year was a Flow Measurement Workshop, to be given during the last week of March. Preparation of the program would conflict directly the internship. If it had not been for Tom Sexton and the hard work of others, I would have been in real trouble. The program was to be given at PVT, and since hands on experience was to be provided, a laboratory facility had to be prepared. During the internship, that's how I spent my weekends. Giving a lecture on the physical principles underlying flow measurement technologies I found myself a bit over committed. The internship concluded the Friday before the week of the workshop. Everything turned out OK, but I was beginning to question the wisdom of my enthusiasm.

VI. The Internship Itself

It was not clear until very late that the proposal might be approved. At first indication that it might I began looking for a suitable company that would have me. I felt, since central Arkansas was the most densely populated industrial area, it would be no trouble finding a place within daily commuting distance. After making some inquiries, I found my assumption to be a bad one. I was told by well informed quality professionals, met through ASQC, that my best bet was Borg Warner in Blytheville AR., a three hour drive. It seems that Borg Warner was not only using SPC, but management was creating and nurturing the kind of atmosphere necessary for it to work properly. I was told that if I wanted to see how it should be done, then this was the only place within easy reach. Jan Partain from AIDC made the initial contact for me and I followed up with a phone call to Mr. Cromer, the plant manager. Having been involved with the Fairfield Bay project, Mr. Cromer was interested in the possibilities this internship offered. He scheduled an interview after reviewing the proposal and examining my background.

The interview lasted the whole day. We began by discussing the goals and objectives of the proposal, their relevance and possible ramifications. We talked about the current condition of industry in the State and what the future might bring. Mr. Cromer gave a description of the development of the quality improvement process at Borg Warner and how SPC

was integrated into their manufacturing methods. I described what I hoped the internship would achieve. It was a long very interesting conversation followed by a tour of the plant. Marty Buthe, the quality control manager, joined us for lunch and the conversation continued. After lunch Marty brought me to an office complex in the center of the plant where he introduced me to Rita Bell, the SPC coordinator. It was at this point I found the desk at which I would spend the next twelve weeks. It would be the best possible place, right in the midst of three production engineers and the SPC coordinator. They would not be able to do much without me being aware of it to some extent. Neither would they be able to escape my questions. We would become friends.

The point at which I became accepted is not clear to me. The interview simply concluded with, "See you in January". The proposal had not been officially approved. There was a substitute teacher waiting in the wings to take my place in the event that it was. Three days before the project was to begin, approval was received. Things had fallen into place, due to no one person's fault. I was at the beginning of a very important experience.

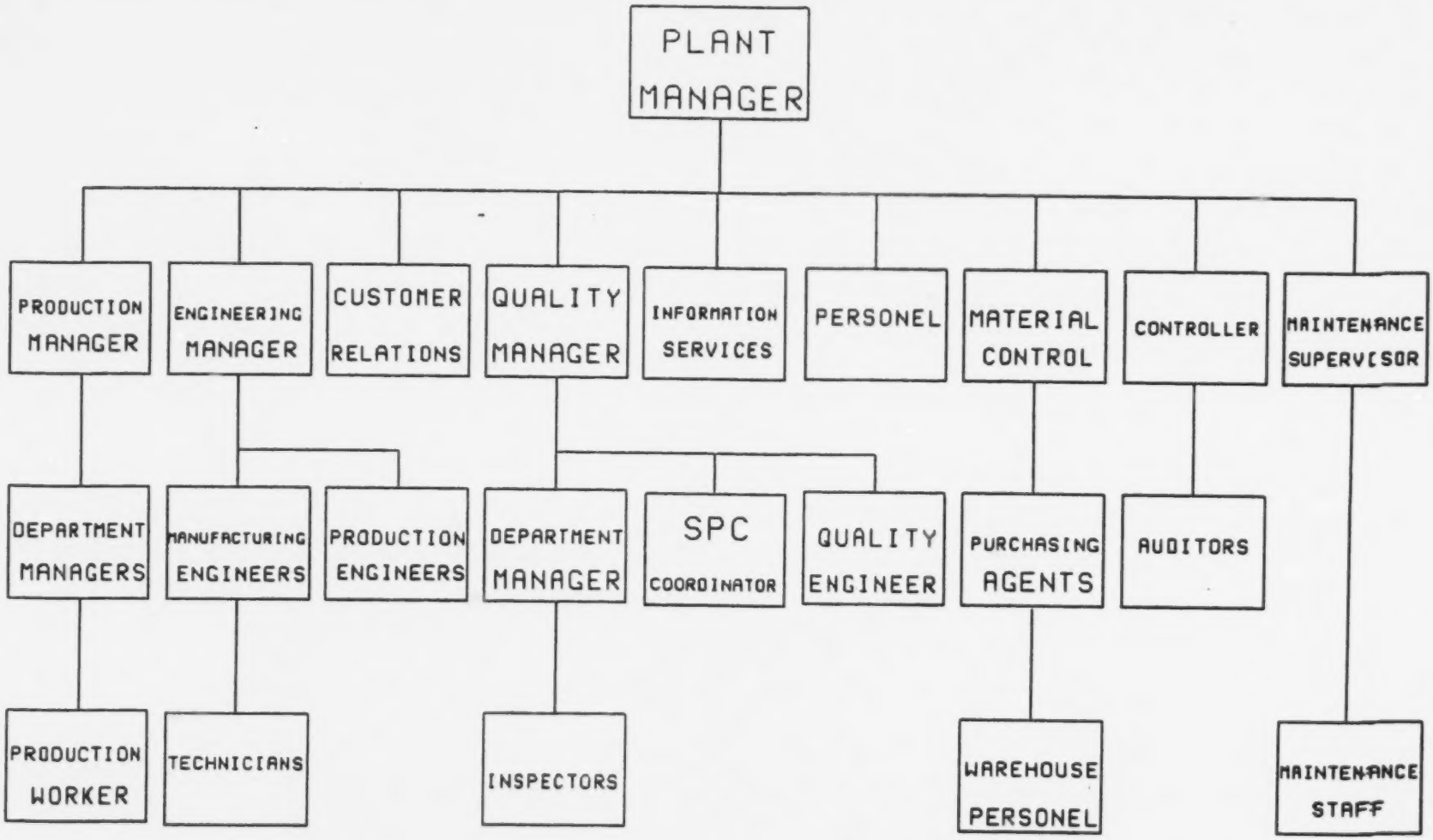
A. Getting Started

Linda Oldman, the personnel manager, arranged for me to meet with a local real estate broker at 10:00 AM, the morning of my first day. By lunch I was moved into the apartment. It would remain unfurnished except for a kitchen, bed, chest of

drawers, work table and chair for the entirety of my stay in Bytheville. Leaving Little Rock between 5:00 and 6:00 AM Monday morning placed my arrival at the plant somewhere between 8:00 and 9:00. For the rest of the week I maintained a work schedule compatible with that of the day shift, beginning at 7:30 AM and leaving the plant between 4:00 and 5:00 PM. Leaving for Little Rock after lunch on Friday allowed me to report to Harriet Frazer, the project coordinator, sometime between 3:00 and 4:00 PM. Checking in, coupled with my responsibilities for the ISA Flow Measurement Workshop, required that I spend my weekends in Little Rock.

1. Conversations with Bill Cromer
2. The Organization

It should be noted that the Blytheville manufacturing facility is only one of many in the Borg Warner cooperation and that what is said here does not necessarily apply to the organization as a whole. As can be seen from the diagram, "COMPANY HIERARCHY", that the Bytheville plant is stratified into four distinct layers, responsibilities having been categorized into nine departments: Engineering, Production, Quality Control, Material Control, Maintenance, Personnel, Customer Relations, Controller and Information Services. The managers from each department make up the plant managers staff. The plant manager provides the direction and philosophy by which plant policy is shaped. The staff provides information and advice in formulating policy and



COMPANY HIERARCHY

then is responsible for seeing that that policy is successfully implemented by midlevel managers among the workers in their respective departments. This is a typical top down management strategy. The primary disadvantage of this four layered arrangement is that the plant manager's staff is necessarily large, making consensus and thus policy formulation more difficult to achieve unless, as in this case, you have people that work well together. The major advantage is that upper level management is in closer touch with plant operations. That is because the vertical flow of information has fever obstacles to overcome. Concerning vertical communications, it should be noted that it occurs quite naturally from the Top-Down, like water down hill. The reason for this becomes apparent when one considers where authority resides. Top-Down communication can easily take the form of telling people what to do. For leadership to get needed information it has to ask for it, generally in the form of reports. Bottom-Up communication must be designed into the system. This means formulating policies and procedures that provide a workable structure. It also means creating an atmosphere where important, but otherwise unsolicited information, can make its way to the top. This is one of the tasks of Quality Management.

3. History of the Quality Improvement Process at Borg Warner.

While at Borg Warner I talked with a lot people from all departments and at all levels within those departments. I didn't speak with everyone, but it was a very big sample,

carried out over long period of time. The conversations were informal and relaxed and I always had the feeling that I had the confidence of the person with whom I was talking. I was accepted and trusted right from the very beginning. My first reaction was to accept this at face value, as if to say; "Well, of course. I am a trustworthy person, I deserve their confidence. There is nothing remarkable in this. It is simply the way it should be." Upon reflection, I reconsider. It is remarkable. Here was a large group of people who as individuals were ready to tell a stranger exactly what was on their mind. They acted like people who knew they had nothing to fear, who knew they could depend on receiving fair treatment, who knew they could express themselves honestly and be respected for it. (Another task of Quality Management: Drive out the fear.)

The course of these conversations always crossed the question; "How have things changed?" The account was always the same. "Before Bill Cromer, the plant was on the verge of going out of business. He turned that around. He radically changed managements approach to people." Bill Cromer was given full credit, by everyone that I talked with, for saving the plant. What actually happened was that Bill found ways of getting everyone involved, so that they all saved the plant. What follows is a brief chronology of the process that made that possible.

In November of 1980 Bill reads "Quality is Free", by Phil Crosby. This results in the Bytheville plant becoming one

of Crosby's clients. In January of 1982 the quality improvement process, according to Crosby's fourteen steps, is begun. This culminates in April of 1984 with The Employee Involvement Day. In October of 1984 Borg Warner, Bytheville becomes a Q-1 supplier to Ford Motor Company. In May of 1985 the plant receives the U.S. Senate Productivity Award. Since that time the Chrysler Penn Star and General Motors Spear-1 have been added to Borg Warners quality status. So the changes that have been going on, began eight years ago. A lot has happened. I know now, at the end of the internship, and to only a limited extent, that it was not easy.

What the people at Borg Warmer went through is not revealed by examining present conditions. On the day of my preliminary interview while Bill was conducting me through the plant he remarked; "Pretty boring isn't it?" He meant that the atmosphere in the plant was calm. People were attending to their responsibilities in a purposeful and orderly fashion. There was no sense of turmoil, no frantic activity. Everything seemed smooth and low keyed. I had the feeling that this is the way it should be, and that it had never been any different. Bill indicated that it had taken a lot of hard work to get it that way and that there had been some pain involved. The changes in direction they had taken had not been easily achieved.

B. Daily Activities

"What was my task again? Oh Yeah. Find out about this SPC/QI thing." With limited light on the subject, where does one begin. The answer - Exactly where you are. I was in a foreign environment and knew next to nothing. So, my goal became - Understand Everything. Pick up every available detail and synthesize as coherent an image as possible. My approach became one of total emersion. It began 12 Jan, 1987 at 1:00 PM, the first time I sat at my desk. I managed to fill in the other half of an overheard phone conversation well enough to ask some reasonable questions concerning the issues being discussed. Cavity 3 on 285 was generating out of spec parts. SPC or audit had picked this up. A decision was being considered to weld off cavity 3, use the mold to create a 3 week supply and then send the it to the vendor for rework. This information was the result of my first conversation with Joe Zaino, production engineer-Injection Molding. There would be many more conversations with many other individuals. I would eventually begin to drown in detail.

At 1:30 P.M., Charlie Holoway, manufacturing engineer-Grey Iron Room and Rita Bell, SPC coordinator, had a discussion concerning the viability of the 144 chart. Does it really matter? Does it produce useful information concerning the "flow of the valve"? What would it take to convince the customer that the chart could be removed or changed without loss of important information? Was this something for the PIT to consider? Does an out of control condition on this

chart really indicate that the process is out of control? If so, is the proper corrective action a tool change? Rita began to explain as Charlie picked up the phone and to call the customer. A combination tool, responsible for the machining of two distinct features would sometimes run out of control on one, but in control on the other. The operator would respond by performing an unrequired tool change. A long term solution would involve additional training for the operators. A more immediate question concerned the way SPC was being used on this aspect of the process. Rita said, "SPC is a tool. You can't afford to be a slave to it". The charting process could not be changed without approval from the customer and so the dialog had begun. Sometimes those in most immediate contact with the process have trouble making their case clear to those with decision making authority. This is a wide spread problem found in all organizations. Quality Management seeks to solve it. Resolution of this situation would finally occur near the end of my stay.

2:00 PM. Charlie hangs up the phone and says, "Let me show you the Grey Iron Room." What I found was a plant within a plant. The process was cast iron machining. It involved five, large, rotary transfer, machining centers. Several different EGR valve bodies were produced from raw casting and then shipped to the customer for final assembly. The operation was complex and noisy. Ear protection was required. I did my best to catch what Charlie was trying to

tell me. I would eventually get to know the process and the people pretty well.

At 3:00 PM I attended an employee's Activity Committee meeting. The membership was made up of employees from all parts of the plant and rotated on a regular basis. They had a great deal of autonomy and organized events such as the Christmas Dinner and New Years Party. They also coordinated activities such as the bowling league and river float. The Flower Committee sent cards and flowers to recognize events, both tragic and joyful, in personal lives of everyone at Borg Warner. All of this contributed to a continuity in the fabric of the company's "culture", by attempting to acknowledge the whole individual and common humanity of all. Humanizing the workplace is another task of Quality Management.

I returned to my desk to organize my notes. So ended my first day. The succeeding days would be much the same; a friendly, organized chaos. In the beginning, it was like reading "The Columbia History of the World" one paragraph at a time, each being selected entirely at random, and then trying to make some sense out of it. It has taken time for things to come into focus.

1. Orientation

During the first week Mr. Cromer arranged for me to meet with each member of his staff. The meetings ranged from one to two hours in length. The discussions were open and free. No relevant question was ignored. Answers were candid and

specific. In retrospect, after experiences with other organizations, I am amazed at the degree to which these individuals were not interested in obscuring anything. This is a tell tail sign that Quality Management is at work.

a) Production

Jan 13, at 9:30 AM, I met with Don Quarles, Production Manager. He described his primary responsibility as the coordination of people, material and machinery to meet a production schedule. To put it another way, his job is to insure that the PROCESSES are operated in an efficient, timely manner. This requires effective interfacing with all other departments in the plant. He and his ten supervisors try to promote an open and close working relationship among production workers. Everyone is encouraged to point out problems or potential problems as soon as they become evident. Production workers are expected to discontinue process operations if they perceive an unsafe condition, or do not clearly understand their responsibilities and how they are to be carried out. Meetings are held on a weekly basis to determine the best way of getting the job done. At Borg Warner that ultimately means; "the right way, the first time".

When I asked Don about SPC he said; "SPC eliminates the tangents created by unsubstantiated opinion". He explained that it was the responsibility of the production worker to chart the process. This involved data collection by some measurement or counting procedure at periodic intervals,

placing that information on a control chart and then determining whether the process had changed in any way. If out of control conditions were detected and a corrective action procedure had been defined for that situation, the operator was to execute that procedure. Otherwise consultation might be required. The quality control and engineering departments were primary sources of information and ideas concerning abnormal process behavior. Process Improvement Team (PIT) meetings also allowed for close evaluation of process performance and corrective action procedures. The PIT had its foundation situated in production. Each process improvement team was organized by product or process.

At the close of the interview, Don gave me a story to read. It was the account of some occurrences in manufacturing that are to this day not well understood. They point in the direction that Quality Management is trying to lead. They deal specifically with those elusive qualities, motivation and initiative. Briefly, the situation was this. One department in a company, consisted of five identical production lines. The engineering staff had done a time study and defined 100% efficiency. It was the production managers responsibility to achieve these quotas. All was going reasonably well on four of the lines. They would range consistently in the upper 90% range. However line 5 was performing abysmally, consistently in the 60% range. To cut a long story short, after management had tried

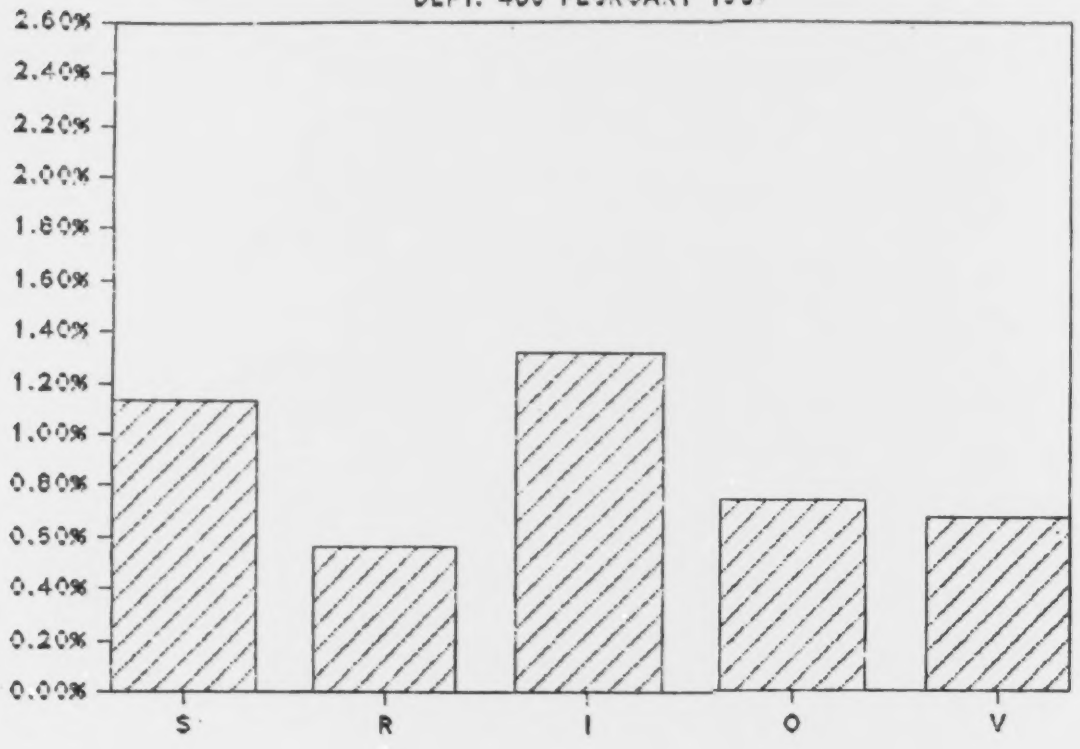
everything at their disposal, they called in a consultant. After examining the situation the consultant agreed to take charge on one condition. He should be given absolute and total control over the operation of line 5. Without knowing what they where agreeing to, management said "OK".
The consultant drew a yellow stripe around line 5. He then informed the workers of the following. They were responsible for everything that happened inside that yellow box. No one, not even the plant manager could cross that line unless invited to do so. They could do anything they considered appropriate. He left them alone and waited. Efficiency fell immediately to around 40 %. Some or the workers were exchanging jobs. Procedures were changed. They began asking for advice and technical support. They continued to make all decisions among themselves. Eventually efficiency began increase. It kept on increasing until it finally reached three times the rated value. Line 5 eventually out performed the other production lines 3 to 1. Why did this happen?

b) Accounting

At 10:30 I met with Shirley the head of the Accounting Department. Principle responsibilities were accounts payable, accounts receivable and payroll. Data from every department in the plant was collected by direct computer input for organization, processing and dissemination in the form of internal and external reports. One of the most important internal reports is the Cost of Quality. This is

COST OF QUALITY PERCENT OF SALES

DEPT. 430 FEBRUARY 1987



NET SALES = $190,107.77

S= SCRAP
R= REWORK
I= INEFFICIENCY
O= OVERTIME
V= MATERIAL VARIANCE

a direct measure in dollars and cents of the cost of not doing the job right the first time. Some obvious factors considered are scrap and rework. Others are more subtle. (A portion of a graphical example for one department is provided in the appendix.) This report lets everyone know how well the quality improvement process is working in the plant and in their department.

It occurred to me, that here, in this department, on paper, was reflected all of the intricacies of the plant's operations. At this stage I was greedy for information. I asked if there wasn't some blue print or flow chart that showed how things fit together. Shirley said that there was and would be happy to get me a copy. A few days later I found it on my desk. This flow chart was a document a quarter of an inch thick, written in small print, proceeding vertically down the page, from one page to the next. Faced with such overwhelming detail and complexity, I realized I wasn't going to get the whole picture. I didn't bother Shirley any more.

c) Customer Services

At 1:15 PM, I met with Peggy Pate, the head of Customer Services. This department is the interface between plant operations and the customer. Peggy illustrated one aspect of her department's function by updating a then current situation involving a manufacturer's recall. Another supplier's component on a subassembly had demonstrated unreliability and the auto manufacturer's solution was to

replace the entire subassembly. Three Borg Warner valves were on that same subassembly. Though they were in no way defective, replacements were required. In the case of a manufacturer's recall, customers are being inconvenienced. It is desirable to get things taken care as smoothly and as quickly as possible. The auto manufacturer needed those valves yesterday. For Borg Warner this meant reorganizing production schedules and turning the crank faster without compromising procedure and quality. In this kind of situation fast is never fast enough. Peggy's role was to motivate expeditious behavior in plant, while keeping the customer politely at bay in the "waiting room". (The proverbial "Rock and the Hard Place" is her place of residence) She made sure she was kept informed of all significant developments as they occurred. In so doing she was able to remove obstacles created by miscommunications and to keep the customer informed with accurate information related to delivery times and other concerns. Peggy said, "I love my job".

d) Personnel

AT 2:15 PM, I met with Linda Oldman the head of Personnel. Linda said, "One of my principle roles is to improve the employees worklife". She compared "Quality of Life" to a boat. Over time, it should rise for everyone. She cited the following as some of the reasons for the low turn over in the workforce. Wages and benefits were good. There was an "Open Door" policy throughout the plant. If any employee

had a problem that was affecting his or her ability to do the job, this provided means for it to surface easily and then be remedied. Workers were expected to decline tasks they perceived as being unsafe. Workers were encouraged to ask for additional information or training if they felt they did not understand a procedure well enough. All employees could become involved in decision making processes that would directly affect their work life. In-plant training and education were provided for those who wanted it. Several GED programs had been successfully completed. Blueprint Reading, Geometric Tolerancing, SPC and Supervisory Training were among the classes that had been offered.

Concerning that "Boat". Linda indicated that plans were under consideration to insure, that everyone in the plant, considered themselves to be in the "Same One". This meant eliminating artificial differences between the "Salaried" and "Hourly" employee. Equality in the parking lot is an example. Aside from functional considerations, the only person given special privilege was the "Employee of the Month". Their parking place was right next to the door. Moving to an all salaried workforce is an ultimate goal, and is expected to take place in the near future. This will create a common ground, upon which, everyone stands with the same footing. People will be compensated in direct proportion to nature of their responsibilities. The goal is

the enhancement of mutual respect and cooperation, and recognition of individual effort and achievement.

e) Maintenance

Brad Dickerson, the head of the Maintenance Department, and I had chances to talk quite often. Training programs involving maintenance and repair of industrial equipment has been my concern for sometime. I was interested in determining what, if any, might be the training needs for the personnel in his department. This was also major concern for Brad. His maintenance staff was made up of well experienced men, but they not had much formal training. I watched them work, and talked with them. These were good mechanics. However, nev technologies were beginning to impinge on their effectiveness.

Brad and I decided to work up a program in an area of need: Industrial Electricity. The outline, in its basic form, had already been written. The next step was to find facilities that could provide the "hands on experience". We visited a local high school and met with a secondary votech instructor. He shoved us his lab, and we decided that it provided a real possibility. Brad set up an appointment with Bill and Linda to get their views. Brad and I made our presentation. (There is some sensitivity in this matter, so I will skip to the final, general conclusion) Bill suggested that logical prerequisites needed to be observed. That meant GED first and then technical training afterwards. As an "educator", that should have been my Line. Bill's

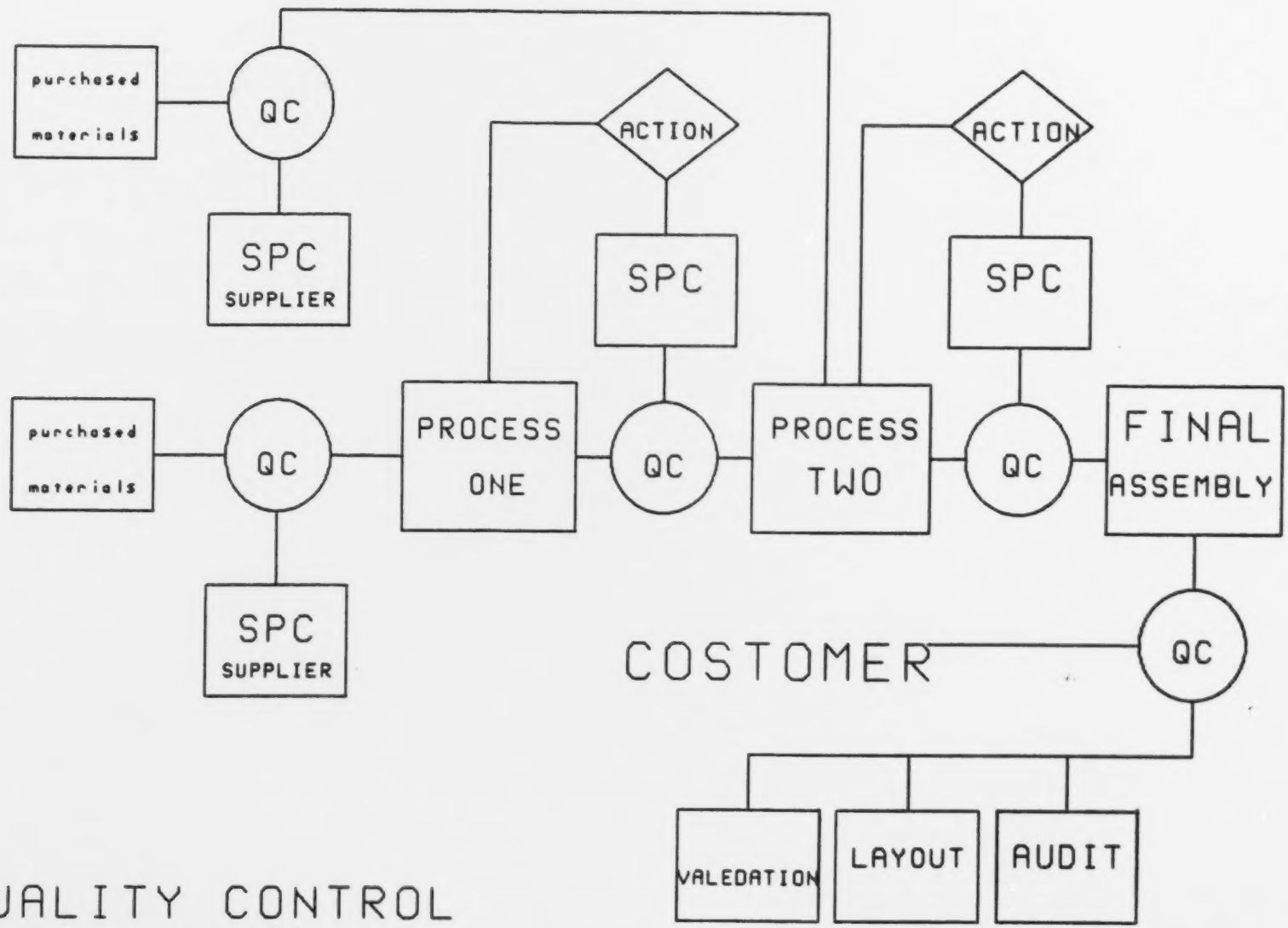
clear sightedness had put things in their proper perspective.

I believe that a prevalent attitude towards training in business and industry encourages its implementation without giving due consideration to the preparation required to maximize its effectiveness. Training will not provide the solutions you are looking for unless it is well thought out. As educators I think we sometimes fall under the same effect for different different reasons. We become involved in marketing our product and end up ignoring similar factors. Especially in the fields of technical training it is easy to find yourself trying to deliver information and ideas that the student is not entirely prepared to receive. Proper perspective on this issue can improve the effectiveness of technical training and education.

f) Quality Control

On Jan 19 at 2:00 I finally had an opportunity to talk with Marty Buthe, Quality Control Manager. Marty appeared to be about the busiest person in the plant. He was involved in every aspect of production and process development. If there was a problem, there was a good chance you would find him involved somewhere in its solution. If there was anyone in the organization, who might border on being indispensable, it would be Marty.

We talked about the internship and about a premise of the Fairfield Bay Project. To wit: It would be possible to teach math instructor's enough about SPC for them conduct in



QUALITY CONTROL

plant training programs for industry. I told Marty that I was interested in putting together a training program that could be implemented as a part of standard, technically based curricula, or be taken inside the manufacturing plant. Marty responded with polite skepticism. He said; "Teaching people to do the mechanics of SPC can be done without much difficulty. Application of SPC to real situations, on the other hand, is more like an art. Once you have the technique, it is learned through experience". After giving this some thought, I nov realize that there is an extraordinary amount that must be known and understood, before you can be expect to be successful. You must understand the process your working with well enough to knov what its limitations are. You must understand the primary and supporting technologies well enough to establish a comprehensive system of cause and effect relationships from one end of the process to the other. You must be able to see the process in terms of the statistics of its outputs. The learning curve here is very steep. It takes a special kind of individual with a special background. I have met three. They are Marty Buthe, Rita Bell and Kay Shrieve. Marty confirmed the basic idea of the flov chart for the quality control function.

g) SPC Coordinator

I saw and talked with Rita Bell, the SPC Coordinator, everyday. She shared what she was doing, while she was doing it. There was never a question that went unanswered.

I formed a pretty good idea of what it takes to be a good SPC coordinator by watching Rita. You have to have a positive outlook, a good nature, an open and active mind, be a people person, and have a technical attitude. You have to care and believe that you can make a difference.

2. Gathering Information

The method of the internship was not clearly defined, either in my mind or in anyone else's, as far as I could tell. There were no existing models to work from. From time to time, to keep me on track, Bill Cromer would ask me about the nature of my mission. I would generally refer back to the goals and objectives as described in the proposal. I now found these not very explicitly defined. My original preconceptions of the way it would be, were being overwhelmed by the amount of information available and the complexity with which it was arranged. I found everything connected to everything else. It became clear to me that SPC was only a small part of the picture.

As already indicated my approach was simple. Watch, listen, question and record. Synthesis would come later. I was given complete freedom. I took small excursions to all parts of the plant, meeting people and engaging in productive conversation whenever possible. It was like finding a door to open and then following the path found waiting there. I would go as far as I could before having to retrace my steps. In the case of the many meetings I

attended, it was like boarding a bus to see where it would take me. I fell into a routine.

It was fourth or fifth week before I woke up. Rita Bell, the SPC coordinator, was waiting for me. She and Charlie Holoway suggested a more organized approach. Concentrate on one part of the plant, the Grey Iron Room. I agreed. I also decided to take a more analytic approach. That meant getting a grasp of the manufacturing and support technologies present. I started flow charting processes. I know now, I should have done this from the very beginning. Flow charting and cause and effect analysis, provide hard information that is easily organized and provides a foundation upon which most discussions can rest. I would profit from this lesson later.

a) PIT meetings

In the beginning I attended at least one Process Improvement Team (PIT)meeting a day. There were twelve PITs and were organized by product or department. For example the "vacuum motor" PIT is product based, while the injection molding and grey iron room PITs are departmentally based. Of the twelve, nine met weekly and three met every two weeks. Frequency of meetings was an internal decision made by each PIT, based upon need. In the meetings company hierarchy was set aside. Everyone had an equal voice. Leadership was a rotated responsibility, whose main function was to address the agenda and maintain order.

b) QIT meetings

The Quality Improvement Team (QIT) is where the improvement process began. In the second of Crosby's 14 steps the QIT is formed from representatives from each department of the plant. The purpose of this team is to affect and direct change throughout the plant in such a way as to facilitate realization of the company's stated mission. Borg Warner Blytheville has been through Crosby's cycle twice. I was witnessing the formation of the third QIT. The membership included production workers, supervisors, secretaries, inspectors and the plant manager. The first meeting elected a chairman and selected someone to keep minutes. A brainstorming session produced the list of the following things to do. Contact "Quality College" (Crosby's organization). Contact previous QIT members to get status update. Reread the first half of "Quality is Free". Formally announce membership of the 3rd QIT. Recognize the previous QIT. Preserve the history.

In all I attended three or four meetings. Development and organization was slow. The leaning curve was very steep at this point. They had not been to "Quality College". It is designed to give some direction and method to the program. They felt their way, concentrating on the goals listed above. As they did, I watched the rapport of the group grow stronger. Seeing this chemistry develop was my principle learning experience in these meetings. Watching people learning how to work together is a consciousness raising experience. Since Mr. Cromer, the plant manger, was

participating, team members that had not had much contact with him, were reluctant to speak up. By the end of 3rd meeting everyone knew him as Bill and a level field of operation had been established.

c) Other meetings

Every two weeks, a group of people from all parts of the plant attended a Leadership Forum. The program was designed by Rita Bell and Debbie Underwood to systematically, improve leadership skills. This was done through a series of classes and activities. They were effective and fun, even though, the desensitization process sometimes caused some discomfort. If you were in the room you had to participate.

d) Technical Support

At Borg Warner measurement and product testing procedures range from the simple to the complex. Technologies as straight forward as the "Go-NoGo" gauge and as sophisticated as mass spectrometry are used to evaluate product quality. At Pulaski VoTech, Industrial Instrumentation and Electronics are my primary responsibilities. When I had the opportunity, I spent time looking over Bennie Harpers shoulder. Bennie is an electronics technician and is part of the technical staff that maintains most of the measurement and control systems in the plant. A lot of these systems were designed and built. Larry, the head technician-engineer, and I spent time discussing the integrity and design of the instrumentation and other

matters. This was experience I could take directly into the classroom.

C. Processes

For the past number of years I have been involved with the development of educational programs designed to train technicians to install, maintain, troubleshoot and repair industrial equipment. I have been primarily concerned with the technologies and applications of the subsystems that make up this equipment. There are four broad categories: mechanical systems, fluid power systems, electrical systems and control systems. I had not given much consideration to the manufacturing processes this equipment might be expected to support. My experience at Borg Warner has added this new perspective.

In the view of the process improvement team these subsystems become black boxes and only act as possible sources of variation in process performance. As illustrated in the cause and effect diagram, other factors that affect the process are Materials, Workforce, Environment and Method. The strength of the PIT is having a membership varied enough in skill and knowledge to be able to isolate a source of variation once detected, determine its cause, and then define and execute the proper corrective action. That means specialization, since no one can be expected to know it all. It also means cooperation. Information and knowledge must be shared. Production, Engineering, the Technical Staff, Purchasing, Quality Control etc. must work together to

create an understanding of the process. A first step is defining the process as a sequence of events, actions or procedures - Flow Charting. Once the process is described, the flow chart can be expanded to incorporate proven procedures that are designed to correct recurring out of control conditions. Defining the process in terms of its variables, and then understanding how changes in each of these affects the output of the process, is essential. In depth understanding does not happen overnight. Even the simplest manufacturing process is complex, when examined closely. Process variables can be classified into primary, secondary, tertiary and more, levels of effect. For example. Someone on the night shift stacks boxes next to a control panel, blocking ventilation. Heat builds, causing some of the electronic components to begin operating outside their specifications. Changes in impedances cause variation in currents and voltages beyond the norm and the output signal to a servo valve becomes too high or too low. The valve opens too far, or not enough and begins mispositioning its tooling. The machinery begins to make scrap. What will be involved in determining the corrective actions required once the situation is detected? A production engineer, electronics technician and maintenance man might be involved in troubleshooting and repairing the equipment. Finding those "out of spec" electronic components might not be easy. Once replaced, however, the process becomes its old self again. This action does not eliminate possible

reoccurrence. Prevention depends on discovering the "root cause". It is probably the operator who remembers "that stack of boxes" he had had to move out of the way, the morning the trouble had begun. In this case the root cause is a procedural one, and once discovered, easily corrected. In manufacturing, problems don't go away unless you make them go away. They won't stay away unless you uncover the root causes and eliminate them. This requires an unrelenting never give up attitude among those individuals who are faced with solving process problems. For them it means learning something new everyday. The the PIT becomes a classroom. Everyone learns from everyone else and from the process itself. When faced with a particularly difficult problem, outside experts are called in. Marty Buthe, Q.C. Manager, seemed to be everybody's favorite. Seminars, conducted by vendors, are another source of important information that should be provided. Management must be prepared to provide the required resources to increase the degree to which processes are understood. Generally, a process that is in control and capable, is a well understood process. I don't know whether the converse is true. Just because you understand what's wrong, doesn't mean you can fix it. When you understand, you are able to recognize and take advantage of a solution when it appears.

D. SPC in Action

1. Case 1

While sitting at my desk early Thursday morning (1/15/87), I noticed a lot of activity in and out of the manufacturing classroom. I checked the calendar. No PIT meeting was scheduled. I decided to investigate. It was a "disaster meeting". Changing to the day shift had brought something of importance to light. An injection molding machine was kicking out leaky valve bodies. The problem must have been serious. This was the most agitation I was to see during my twelve weeks. This problem got the immediate attention of the ten individuals that made up the injection molding process improvement team. Everyone was active. Many were in small group discussions exploring possibilities, making assumptions, placing their bets - one conjecture battling another. Someone was studying the valve seat under a microscope. Others were searching through a large stack of records - SPC charts for that mold. To make it easier someone started taping these to the classroom wall in chronological order. Soon most of the people were standing around the perimeter of the room studying those charts. A couple of polite arguments were still going on. The tool room was insisting that it could be anything, but certainly not a not mold maintenance problem. "It was probably caused by the regrind being mixed with virgin material." Then Joe Zaino, who had been quietly studying those charts, found something. He discovered a change in process behavior beginning on the 12'" of January, right after the mold had returned from the tool room for cleaning. The group

settled. Someone went to the board and the team started brainstorming for a course of action. Environmental conditions were ruled out.

1. Test the regrind theory by running 100% virgin material.
2. Check the heat ban temperature.
3. Check the accuracy of the leak tester.
4. Go to first setup conditions.
5. Layout core pins.
6. Check regrind for fiberglass.
7. Check material temperature from the barrel.
8. Examine the mold.

The next step was to prioritize and assign responsibilities. The leader said, "someone needs to do this". And someone said "I'll do it". Everyone was anxious to get things back to normal. As assignments were taken, the room emptied. Soon I was sitting there by myself. The whole thing had lasted about thirty minutes. In this free work envirohment, a follov up meeting wasn't necessary. Information was exchanged and new decisions made when and where ever it was convenient. An aisle of the production room floor was a favorite place for productive encounters.

The mystery had been solved just after lunch. Close examination of the core pins revealed a lack of shininess when compared with new ones. Installing new core pins had confirmed someone's suspicion. Good parts were then produced. Porosity had been transferred from the bad pin to

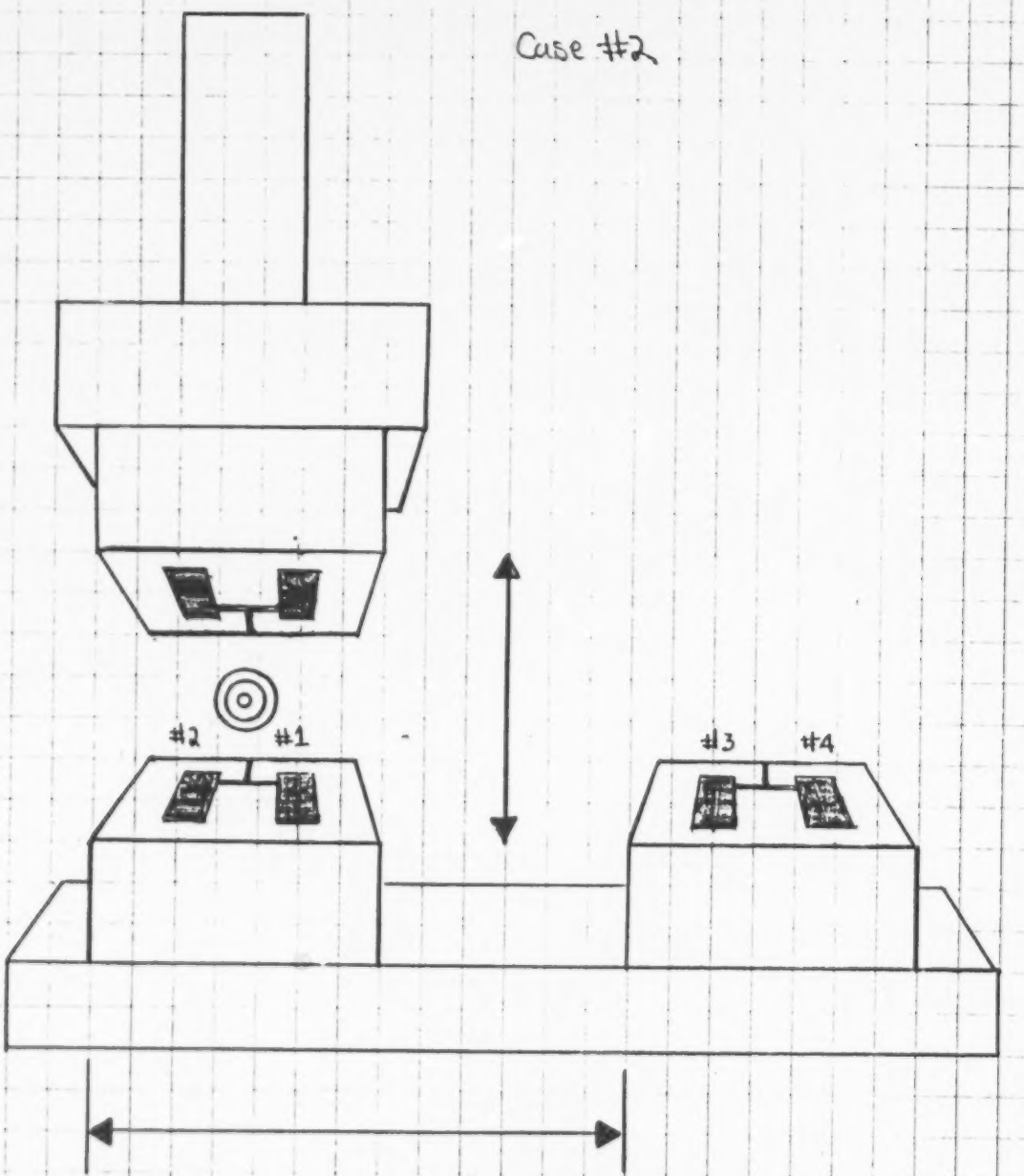
the valve seat. What was the root cause? The tool room examined its records. During mold maintenance the core pins had been polished. After consulting the vendor, it was discovered that the recommended materials had not been used. A written procedure for core pin cleaning was instituted to prevent reoccurrence. Case closed.

2. Case 2

Statistical methods don't have to be institutionalized. They can be used when a situation presents itself. I was walking down the aisle toward injection molding when I met Jean Scott, Quality Control Supervisor for that department. She was carrying a basket full of valves that had just been encapsulated. This small percentage of the total batch, had gas burns, making them defective. The frequencies of this occurrence was on the increase. Jean was in the midst of collecting more specific data related to the problem.

To understand Jean's actions you need to know something about the process. The figure shows a flow chart for the "air bag solenoid valve". The bobbin is the product of an injection molding process. The solenoid coil is then wound on the bobbin. This is then encapsulated by an injection molding process and then sent to final assembly where the pole piece, armature and seat are installed. The whole unit is then subjected to a highly sensitive leak test. The burned parts were coming out of the encapsulation process. The figure illustrates the working relationship of the productive components of the type of injection molding

Case #2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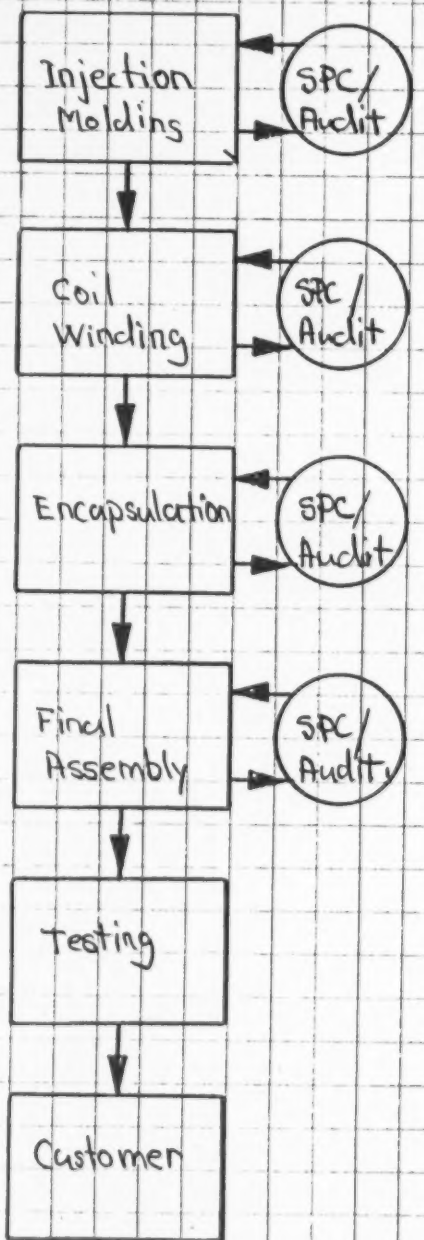
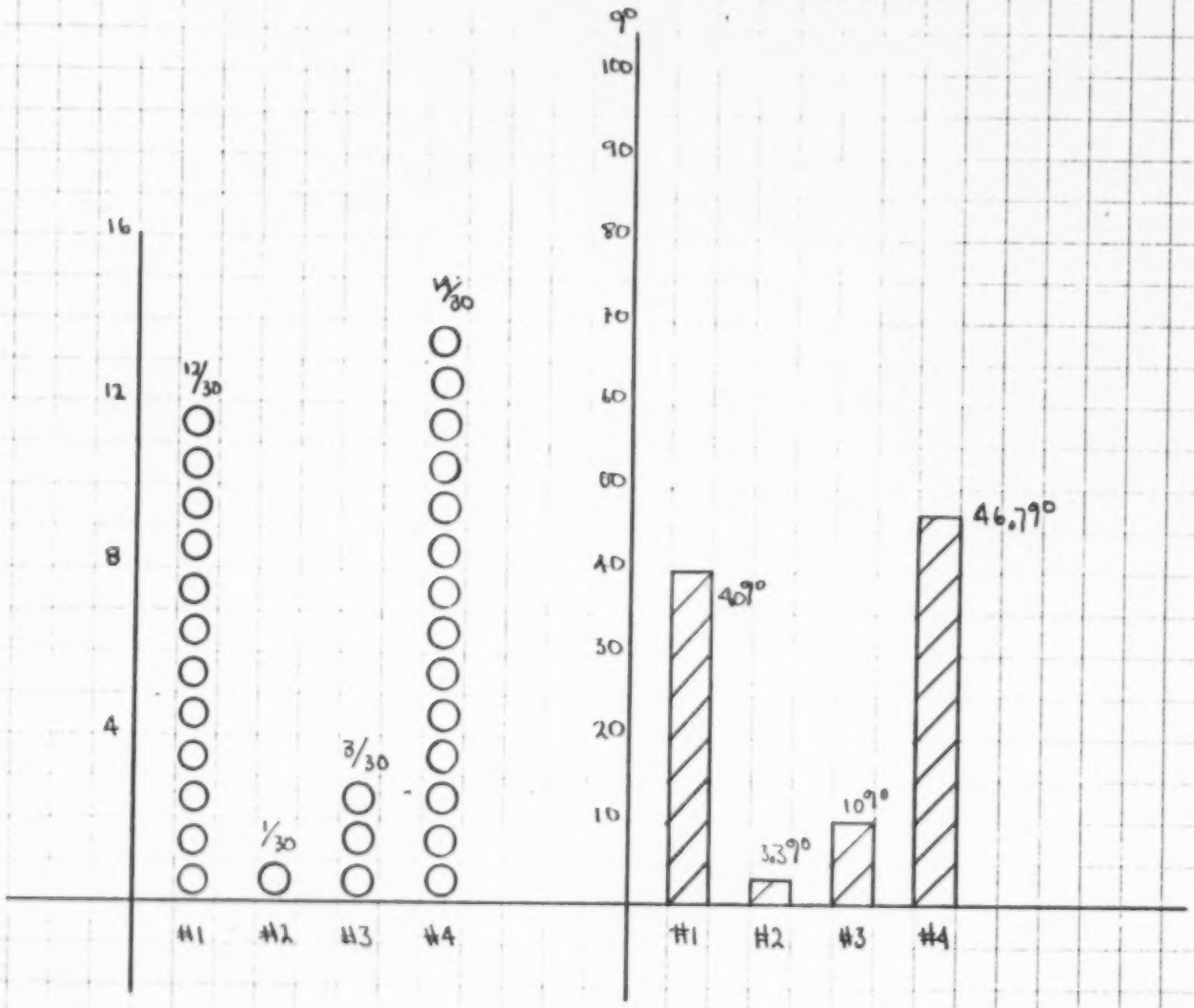

Injection Moldins
SPC/ Audit
Coil Winding
SPC/ Audit
Encapsulation
SPC/ Audit
Final Assembly
SPC/ Audit
Testing
Customer

Case #2


16
12
8
4
12/30
1/30
3/30
14/30
#1
#2
#3
#4
90°
100
90
80
70
60
50
40
30
20
10
40.9°
3.3°
10.9°
46.7°
#1
#2
#3
#4

machine used for encapsulation. The mold is in three parts. The top half descends to form two complete cavities with with #1 and #2 of the bottom half of the mold. The nozzle then comes forward and molten plastic is forced into the mold. At the end of the machine cycle the top half of the mold retracts and the lover table moves to the left. The operator removes the two encapsulated valves, while the upper half again descends, this time on the right hand half forming parts with #3 and #4. After the top half is retracted, the table moves back to the right. The process is continuous. Of the valves in the basket some were from each of the cavities. Jean did a histogram on this population for presentation in the next Injection Molding PIT. As can be seen from the graph of the 30 in the sample, 12 were from cavity #1, 1 was from cavity #2, 3 were from cavity #3 and 14 were from cavity #4. Gas burns can be produced when the air in the cavity cannot escape as the plastic enters the mold. It can be caused by improper venting in the molds construction. It can be caused by contamination on mold surfaces conjesting existing vents. Molds need to be cleaned on a regular basis. What does the histogram tell you about the problem? Right. There is a high degree of probability that there is something wrong with the right cavity of the upper half of the mold. After the tool room had increased the size of the vents, the problem disappeared.

E. The Mini-Internship at Monroe Automotive

Toward the middle of my stay at Borg Warner, Bill suggested that experience at another company for a week's time might be beneficial. I agreed. Inquiries among companies in the surrounding area led no where. Bill finally called Kay Shrieve, the SPC coordinator at Monroe Automotive in Pargould AR. She was a former employee, a Fairfield Bay participant and understood the nature of the project. Her plant manager accepted the idea of me spending a week on the premises to learn what I could about their commitment to quality, and what techniques they were currently using. This internship within an internship, began Mar 9 and lasted for five days. Parigould is a one hour drive from Bytheville. I would arrive at 8:00 AM and leave around 4:00 in the afternoon. On Friday I drove directly back to Little Rock to report. I was anxious to see, after my experiences at Borg Warner, how long it would take to gain a functional understanding of the companies operation. (An interesting test)

1. History

Monroe's role as an original equipment manufacturer (OEM) placed it in the same circumstances that Borg Warner had found itself. The auto manufacturers were requiring use of SPC and statistic evidence of process capability. This put suppliers like Monroe in a difficult situation. As they say in the Foreign Legion, "Walk or Die". Among the first steps taken was to conduct SPC training for operators and inspectors. This was set up with the help of Lee Spurlock,

the local industrial coordinator. The class was taught by Kay Shrieve, the then SPC coordinator at Borg Warner. After a round training was completed, management took steps to apply it on the production floor. After some months, upper management realized that they needed a person to coordinate all efforts involving SPC. They made Kay an offer she couldn't refuse. Since that time major positive developments have occurred.

2. Integration of SPC

When Kay first arrived on the job, she found SPC charts everywhere. She told me that the natural tendency of a company who is committed to the adoption of SPC, but still in the early stages, is to over chart. "If it is a variable - chart it." She had begun the process of separating the important from the unimportant. For example. In the beginning, there were over sixty charts being maintained in the powdered metal department. At the time of our conversation, that number had been reduced to less than twenty. The first people trained in SPC fundamentals were the production workers and inspectors. Kay was currently conducting classes for those in the engineering department. When asked if she thought was proper order she said that it should have been just the opposite. Training engineering and upper level management first and then move to the next level. She feels that a top-down approach is best.

3. The Processes

I was taken on plant tour soon after I arrived. The atmosphere was completely different from that at Borg Warner. The plant was larger. The blue interior and fluorescent lighting gave the impression of a bright moonlit night. (Borg Warner had a yellow interior with a sulphur based lighting, that made you think of an open field on a bright sunshiny day. Both had their appeal.) There were more people integrated into the production processes. The frequency of activity was higher. It was noisier. Other than raw materials, Monroe buy's few purchased items. All parts that make up a shock absorber (50 or so) except for rubber grommets, plastic washers and the like, are fabricated in house. The tour was great. We started at the beginning and went to the end. Later that week, I returned to the shop floor, on my own. I wanted a flow chart of the plant. No one bothered me. I investigated to my hearts content. I loved it. It wasn't possible to talk with anyone; they were too busy and it was too noisy. That didn't matter. It was an important experience. I discovered that I could develop an understanding of a complex operation quickly.

Below are listed the major processes I found in the plant. It had been my intention to treat these the same way I intended to treat those I found at Borg Warner. For the same reason I am unable to do so. At the end of the week I made one more trip to shop floor and finished the chart.

a) Powdered Metal
b) Machining

c) Plating
d) Metal Forming
e) Welding
f) Assembly
g) Testing
h) Painting and Packaging

VII. Succeeding Events.

Upon completion of the internship I returned to Pulaski Votech just in time to follow through with ISA Flow Measurement Workshop. It was a modest success.

A. ASU SPC Workshop

In the late spring of 1987, I had the opportunity to attend a one week workshop conducted at Arkansas State University Beebe. It emphasized mastery of SPC fundamentals for potential SPC instructors. Some of the same people from Fairfield Bay were there. This would prove to be a good review for us. As for the others, it was interesting to watch as they became acquainted with these new ideas. I was able to observe some of the same changes I had gone through the previous year in those around me. The enthusiastic new comer tends to exclaim, "All of this is so obvious. It's simple. Why can't industry see it?"

The program was excellent. We worked twelve hour days and covered all the basics. We constructed a lot of charts. At the end of the week we did a simulation. Everyone learned a lot and had fun doing it. I had the program for the last night. I was to talk about my experiences at Borg Warner. I work well in a student-teacher relationship, but I do not address my piers with a high degree of confidence. I prepared diligently. I had an eight page outline. I had transparencies. I did everything I could to get ready. I was nervous. Jack Jackson introduced me. My mistake was trying to tell a funning story. Even though true, and I

still think funny, no one laughed. I froze. My audience became concerned. I began to hyperventilate. I knew I had to get control of the situation. With short, gasping sentences, I told my audience that they would have to watch me attempt to breathe deeply. That broke the ice. After a couple of minutes, I began. I didn't follow my notes. The talk flowed out effortlessly. The two hours scheduled, turned into two and a half. Its the only time I've ever received applause for speaking. I began to realize how much the experiences at Borg Warner had become apart of me. I suggested that if anyone were interested, Borg Warner would entertain another internee.

B. Conversations with a potential client.

During a Quality Improvement Team meeting in Febuary a phone call had come through for Bill. A company in central Arkansas was asking for advice concerning SPC and QI training programs. The recommendation from Mr. Cromer was Crosby's method. I heard no more about this until I returned to PVT. One day the industrial coordinator asked me to meet with upper level management personnel from this same company. The purpose was to discuss SPC training. The Vice President of Manufacturing, the Engineering Manager, a Quality Control Specialist and I had lunch. I made plain my limited background. That was passed over, and I was asked to submit a proposal for training. The outlines I prepared can found in the appendix.

Somewhere between fifteen and twenty hours were spent in meetings, trying to find something that would work. In the end it became clear to me that their goals and mine were not compatible. They considered SPC to be a tool for the production worker or inspector to use. In their mind, these were the only people that needed to be trained. They felt that upper level management, and even engineering, not need to get directly involved. They were trying to institute a Quality Circles program, but its activities were to be well insulated from the management function. They were not interested in making more permeable the barriers obstructing vertical communications. They wanted to direct a quality improvement program, not participate in one. Eventually we stopped calling each other.

C. SPC Training

While negotiating with the company mentioned above, the industrial coordinator put me in touch with the production manager of a small company in Jacksonville. At the first meeting we decided to put together a class and work through the Transformation of American Industry Program. (My outline for the program is in the appendix.) He knew that this would be my first attempt. His attitude encouraged me. He said, "We will all learn something together."

First I went to the shop floor. I met some of the people, and flow charted the processes. Next, I ordered the books and set up a schedule for the video tapes. A group of twentysix volunteers, including production workers,

maintenance staff, inspectors, secretaries and department heads, attended class from 3:45 to 6:00 PM, every Tuesday for about fifteen weeks. At first the idea of voluntary participation seemed like a good idea. Everyone would be there because they wanted to. I failed to consider that the converse was also true. Attendance became a problem around the fifth week and never went away. We fought some up hill battles, but completed the course of study. Math and reading skills should be given due consideration before beginning a program like the one undertaken. (I should have learned that from Bill Cromer.) The video tapes tended to put people to sleep. If I were to do it again, I wouldn't use them. Finally, a key department head decided that he would not be able to participate. He maintained that "he was participating", and "was supportive" of our efforts. He just couldn't come to class. He "had to get those parts out." This, in conjunction with another factor, may be dealing the effort a fatal blow. Around the eighth week I woke up to the fact that a key ingredient was missing. That was, "the person who would make the program work after the training was over". Marty Buthe's remark's rang in my ears. "It's not hard to do SPC training. Applying SPC, on the other hand is an art. That's difficult if not impossible to teach". I began pointing this to the companies management out at every opportunity. I suggested that one of two things had to happen. Either someone within the organization had to start becoming an SPC expert, or someone

had to be brought in from the outside. At this point, seven months later, I don't think either one has happened.
We had a graduation ceremony in the Spring of this year. I do believe some positive things were accomplished. We opened a very important door and looked around. New possibilities were discovered. Skills were developed. Most important, people are talking with each other in new ways. The Process Improvement Teams that were formed (four in all) are still functioning. As long as they are, whose to say where things will lead? I have learned that Quality Improvement is an evolutionary process. For me, this was an important experience, but as long as my other responsibilities demand so much of my time I don't think I will do it again.

D. Continuing Involvement with Industry

As a result of the success associated with our midlevel management training program in electronics, we were approached by the same company for assistance in solving a training problem. Due to advances in technology, certain job descriptions were being changed to include additional responsibilities. These new responsibilities required a technical background in basic electricity/electronics. Qualification for the new jobs was to be determined by a test. Working closely with the company, PVT helped in the development and implementation of a 320 hour program, taking place over eight weeks. I am happy to report that it was a major success.

VIII. Conclusions

It has been two years since this all began. Now I'm faced with draving a bottom line and totaling the results. There have been many positive developments addressing the basic issues of Statistical Process Control and Quality Management. Most of these are probably associated in someway with the Quality Task Force. Since I am not current with their activities, I will decline comment as far as the big picture is concerned. What I do what to talk about is curriculum development and in plant training.

About two and a half years ago I started getting involved with activities that might be considered peripheral to my job description. I had been told, and believe to be true, that Technical Education should serve business and industry as well as the student. As my involvements and committments mushroomed, one particular concern began to develop and hold my attention. The experiences of the internship stimulated its development. Now that my focus is beginning to narrow again, that concern remains central, and relates to the definition of the learning process in terms of appropriate and executable curriculum. My thinking was influenced by the concepts and approaches I came in contact with, through my exposure to SPC. I do not mean to imply that these ideas are orignal. They are not. They just seem that way to me, since they are the product of a personal search for answers. I learned alot from the people I met at Borg Warner.

A. The Educational Process

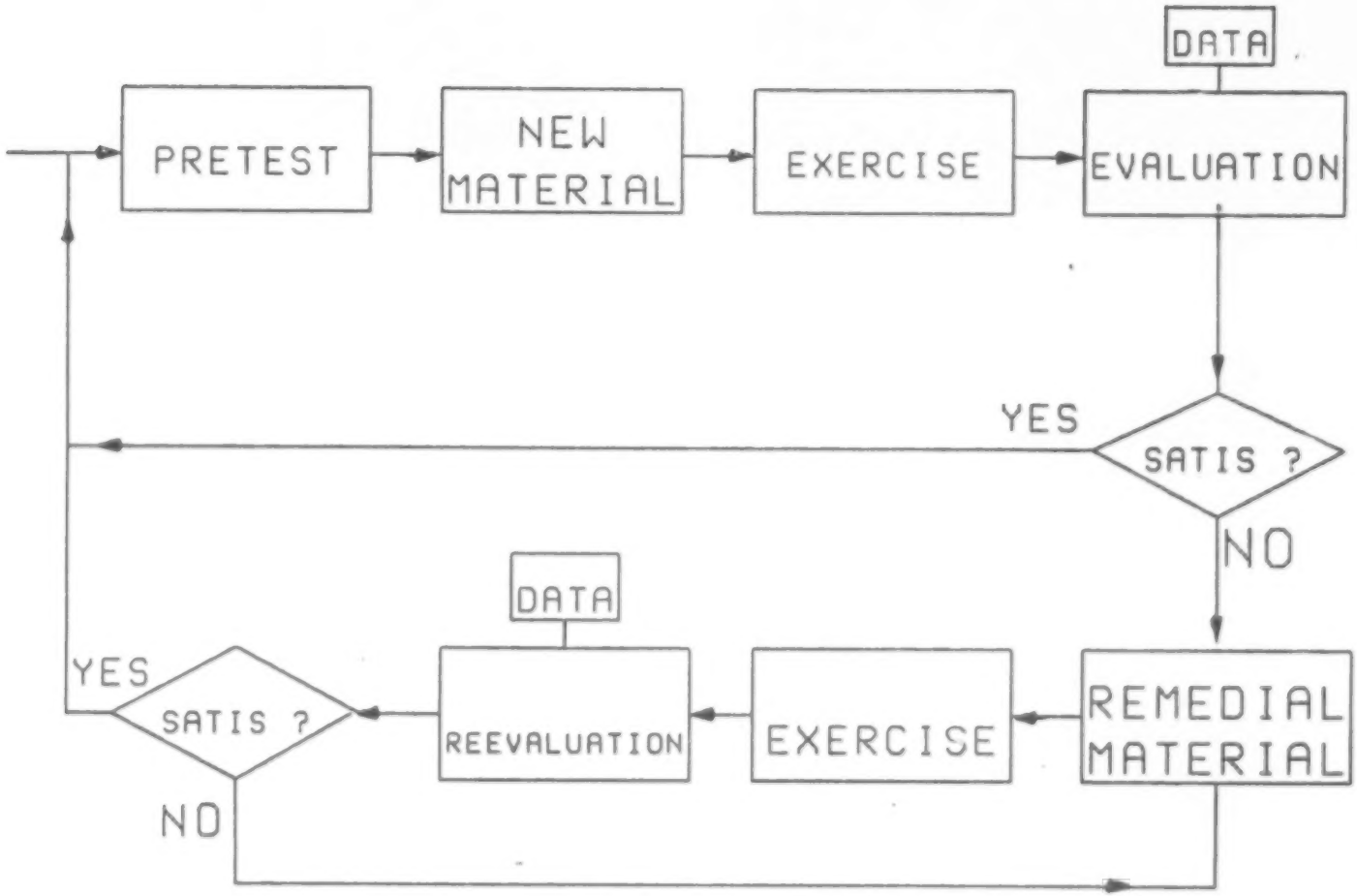
How does the learning process look from the vantage point an SPC approach provides? The diagram illustrates one possible answer to that question. The student enters the training loop by being pretested to determine his current level of proficiency in areas important for success. New materials then are presented that are in accord with his/her operating level, and the goals and objectives of the program. The student internalizes the material through exercise. At an appropriate point his/her progress is evaluated. This activity is a data source for two concerns. First the students level of success can be judged and a decision made whether new or remedial material should be the next step. Second the data can be used over time to determine the effectiveness of the training materials and the way they were presented. This provides a solid base for program improvement. The remedial loop is the same and can be duplicated as many times as is necessary and practical.

B. The Curriculum Development Process

The block diagram is straight forward. The next step is a detailed assessment of content. The following addresses technical training related to industrial processes and equipment.

Curriculum development should proceed from an analysis of the manufacturing process and the technologies that support it.

1. Determine which manufacturing processes are to be addressed through a survey of local industry.



EDUCATIONAL-TRAINING PROCESS

2. Analyze each in terms of the technologies that are associated with it.

3. Analyze each technology for course development.

   a. Determine the concepts, physical principles and mathematical models that apply.

   b. Determine the operational characteristics of the systems used for process realization.

   c. Determine the operational characteristics of the components used to realize each system.

   d. Determine the skills required for positive interaction with the process and its technologies.

4. Develop the course ware that pertains to each technology.

   a. Develop a course outline that defines the goals and objectives of the course and lists the topics to be covered.

   b. Subdivide the course into unit plans that consist of more specific goals and objectives and a list of the lessons of which it will consist.

   c. Develop lesson plans with stated objectives, methods, materials and evaluators.

   d. Develop Learning Activity Packages for each lesson. The LAP should consist of the following.

      1. Goals and Objectives

      2. Educational Resources required

      3. Presentation of the subject matter

         a. Concepts and Principles

b. Information

c. Examples and Illustrations

4. Learning Activies

a. Written Exercises

b. Laboratory Exercises

c. Job related task training

5. Evaluation

a. Criteria

b. Evaluating Instruments

c. Analysis and Feedback Mechanisms

6. Remedial Activities

Because of the way the LAP is designed, the learning process becomes less teacher dependent. A greater uniformity in delivery comes about. The students positive motivations are enhanced by becoming more directly involved with his education.

Once developed, Learning Activity Packages can be assembled into a Curriculum Resource that could serve any client, public or private, anywhere the required facilities exist. Training programs could be assembled according to the flow chart shown in the diagram.

1. Establish Goals and Objectives

2. Determine the operating level of the participant through diagnostic testing.

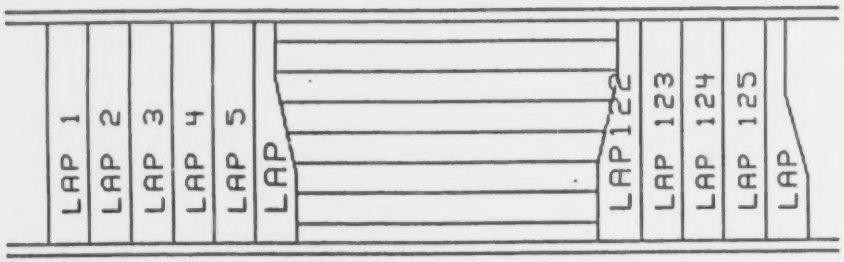
3. Assemble and execute the Training Program.

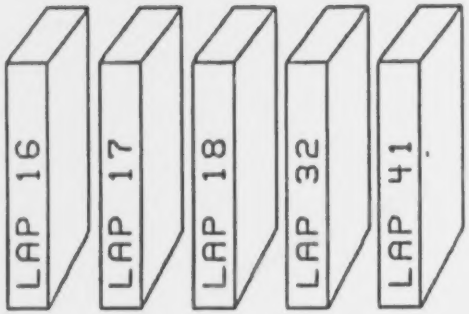
4. Administer a Final Evaluation.

C. Process Evaluation and Improvement

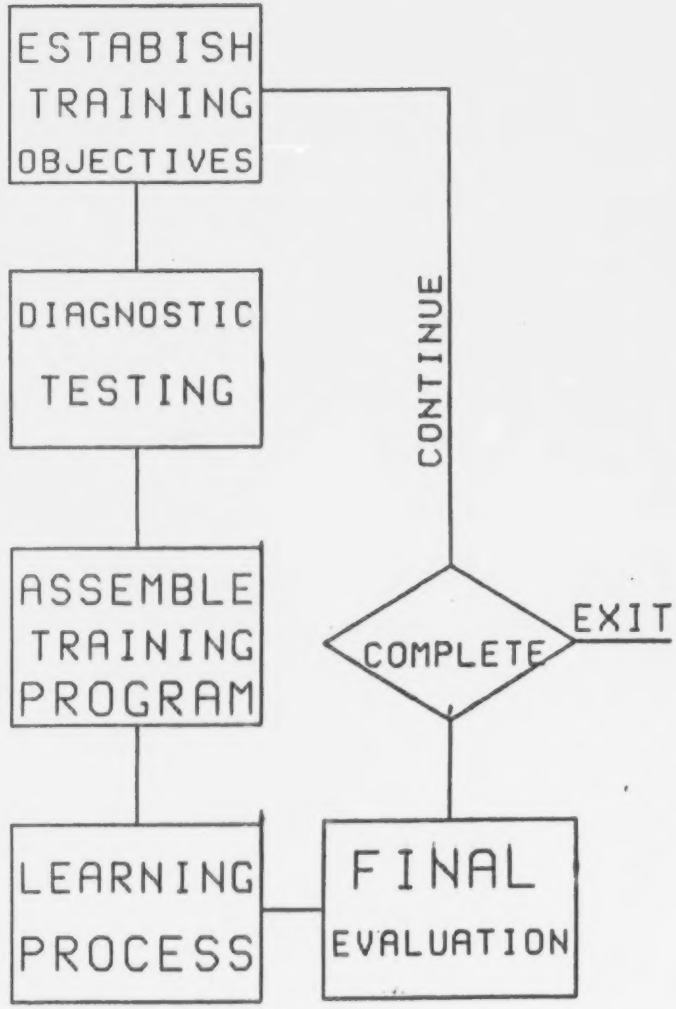
THE LEARNING ACTIVITIES PACKAGE

- GOALS AND OBJECTIVES
- EDUCATIONAL RESOURCES REQUIRED
- PRESENTATION OF SUBJECT MATTER
  - CONCEPTS AND IDEAS
  - INFORMATION
  - EXAMPLES AND ILLUSTRATIONS
- LEARNING ACTIVITIES
  - WRITTEN EXERCISES
  - EXERIMENTATION
  - TASKS
- EVALUATION





CUSTOMIZED TRAINING PROGRAM



CURRICULUM RESOURCE

Once the Curriculum Resource exists, it immediately avails itself to evaluation and subsequent improvement. As time passes its value increases. It becomes more effective and more adaptable to the needs of the people who use it. It would have the effect of improving the quality of life for many people and enable industry to find easier answers to their training needs.

APPENDIX

Transformation of American Industry

The following is a functional description of the TAI Program that was conducted from Aug into November of 1987.

Course Outline

Module #1: The Transformation of American Industry

Objectives

1. Discuss the impact of foreign or domestic competition on "The Companies" organization.
2. Describe the "Detection" system of operation.
3. Describe the "Prevention" system of operation.
4. Explain how improved quality leads to productivity, sales, competitive, position, profitability and the creation of jobs for Americans.

Content

I. Current State of the American vs. the World Economy
II. The Need for New Attitudes in Manufacturing
    A. The Detection Mode
        1. The Old Quality Control Model
    B. The Prevention Mode
        1. Statistics and Manufacturing
        2. Process Improvement
    C. The Quality Culture
III. The Idea of "Continuous Improvement"
IV. Exercises
    A. Class Discussion

Module #2: Deming on Quality and Productivity

Objectives

1. State examples of inhibitors to quality and productivity within their own organization (Deming's 14 Points).
2. Identify inhibitors which are caused by the "system".
3. Outline a possible management action plan to eliminate the inhibitors identified as "system caused".

Content

V. Historical Perspective
VI. Management's Responsibility
VII. A closer look at Process Components
VIII. Deming's 14 Points
IX. Exercise
    A. Class Discussion

Module #3: The Transformation Process: Model for Quality/Productivity Improvement.

Objectives

1. Describe the Transformation Process Model in detail.
2. Identify individuals in their own organizations who should be represented on the Quality/Productivity Team.
3. Plan for the use of the Transformation Process in their own organization.

Content

X. A Vehicle for Quality and Productivity Improvement
    A. The Shewhart Cycle
        1. Project Selection
        2. Project Implementation
        3. Project Evaluation
        4. Continuing Improvement Strategy
    B. The Q/P Team
        1. Membership
        2. Training
            a) Quality Management Principles
            b) Problem Solving Techniques
            c) Statistical Process Control Techniques
            d) Employee Involvement
        3. Mission
XI. Exercises
    A. Select Q/P Teams
    B. Train Q/P Teams

Module #4: Project Selection

Objectives

1. Participate in a brainstorming session to generate quality/productivity improvement ideas.
2. Participate in the generation of criteria from which to evaluate the above ideas.
3. Obtain the data necessary to actually evaluate the above ideas.
4. Participate in the selection of a project for their own organization.

Content

XII. Problem Solving Techniques
    A. Brainstorming
    B. Evaluation Criteria
    C. Prioritization
XIII. Exercises
    A. Utilize Brainstorming Techniques
    B. Generate Criteria
    C. Prioritize the Results

Module #5: Project Implementation: Data Gathering & Problem Solving.

Objectives

1. Construct a Flow Chart for the process involved in their selected project.
2. Construct a Cause and effect Diagram for their selected project.
3. Construct a Pareto Chart using data from the Student Activity Guide or from their own organization.
4. Explain the differences among nominal, ordinal, interval and ratio data.
5. Develop a plan for gathering data on their own projects.

Content

XIV. Data Gathering Tools
    A. Defining the Process
        1. Process Technology
        2. Flow Charting
    B. Determining Sources of Variation
        1. Cause and Effect Diagrams
        2. Prioritization of Causes
XV. Kinds of Data Defined
    A. Nominal
    B. Ordinal
    C. Interval
    D. Ratio
XVI. Sampling
    A. Systematic Random Sampling
    B. Stratified Sampling
    C. Cluster Sampling
    D. Judgment Sampling
XVII. Data Recording Techniques
    A. Check Sheets
    B. Pareto Analysis
XVIII. Sampling Procedure
    A. Sample Planning
    B. Normalization
    C. Data Collection
XIX. Exercises
    A. Flow chart the process associated with the selected project.
    B. Construct a cause and effect diagram for sources of variation in the process.
    C. Data Types from Organization Data.
    D. 100 % Sampling Exercise.
    E. Construct a Pareto Diagram from Organization Data.
    F. Develop data gathering plan for the selected project.

Module #6: Project Implementation: Data Analysis & Interpretation.

Objectives

1. Describe data sets in terms of:
   a. Central Location
   b. Variability
   c. Shape
2. Construct Frequency Distributions and Histograms.
3. Describe the characteristics of normal distribution.

Content

XX. Basic Statistics
   A. Central Tendency
      1. Mean
      2. Mode
      3. Median
   B. Frequency Distribution
      1. Class Characteristics
      2. Tally Sheets
      3. Cumulative Frequency
      4. Relative Frequency
      5. Histograms
   C. Variation
      1. Range
      2. Variance
      3. Standard Deviation
   D. Characteristics of a Normal Distribution
XXI. Exercises
   A. Basic Statistics on Organization Data
   B. Histogram on Organization Data

Module #7: Project Implementation: Process Control [X(bar) and R Charts]

Objectives

1. Define Statistical Process Control as the first step of Project Implementation.
2. Construct X(bar) and R Charts using sample data and project data.
3. Calculate control limits.
4. Interpret control charts.
5. Establish a plan for action or additional data gathering based on their own control charts analysis.

Content

XXII. Detection and Prevention Systems
XXIII. Common and Special Causes
XXIV. Variation
XXV. Control Charts
    A. Data Gathering
    B. Subgrouping and Sample Size
    C. X(bar) and R Chart Construction
        1. The Mean
        2. The Range
        3. The Grand Average
        4. Control Limits
    D. Percentage of the Normal Distribution
XXVI. Symptoms of Out of Control Conditions.
XXVII. Corrective Action on the Process
XXVIII. Exercises
    A. Construct X(bar) and R Charts
        1. On simulated data
        2. On selected project data

Module #8: Project Implementation: Process Capability

Objectives

1. Explain why it is necessary to establish process control before capability can be assessed.
2. Describe the difference between normal and non-normal distributions.
3. Evaluate the capability of a normal process and a non-normal process using sample data and data from their own organization.
4. Express the above capability evaluations in terms of:
a. Percent above specification and below specification.
b. Cpk index.

Content

XXIX. Process Control vs. Process Capability
    A. Process Capability Flow Chart
        1. Special Causes and Process Control
        2. Common Causes Process Capability
    B. Capability Evaluation
        1. Normal Distribution
        2. Non-Normal Distribution
    C. Use of the "Capability Analysis Sheet"
    D. Types of Distributions
XXX. Exercises
    A. Determine Process Capabilities
        1. Simulations
        2. Selected Project

Module #9: Project Implementation: Median and Individuals Charts.

Objectives

1. Construct and interpret a median and an individuals moving range chart using sample data and data from their own organization.
2. Evaluate process capability based on the above analysis.
3. Explain the advantages and disadvantages of the various kinds of variables control charts.

Content

XXXI. The Median Chart
    A. Uses and limitations
    B. Construction
    C. Evaluation of Data
XXXII. The Individuals Chart
    A. Uses and limitations
    B. Construction
    C. Evaluation of Data
XXXIII. Exercises
    A. Construct a Median Chart
    B. Construct an Individuals Chart

Module #10: Project Implementation: Attributes Charts

Objectives

1. Operationally define an attributes characteristic within their own organization.
2. Construct and interpret P, nP, C and U charts using sample data and data from their own organization.
3. Evaluate process capability based on the above control chart analysis.
4. Identify appropriate applications of attributes charts within their own organizations and select the chart which should be used in each case.

Content

XXXIV. Attribute Data
XXXV. Attribute Charts
    A. P Chart
        1. Application
        2. Preliminaries
        3. Mechanics
        4. Interpretation
    B. nP Chart
        1. Application
        2. Mechanics
        3. Interpretation

C. C Chart
    1. Application
    2. Mechanics
    3. Interpretation
D. U Chart
    1. Application
    2. Mechanics
    3. Interpretation

XXXVI. Exercises
A. Construct: Simulation and Organization Data
    1. P Chart
    2. nP Chart
    3. C Chart
    4. U Chart

Module #11: Project Evaluation

Objectives

1. Discuss the need for project evaluation as part of the Transformation Process.
2. Establish a plan for project valuation on their own projects.
3. Contribute to a presentation of their project.

Content

XXXVII. The Evaluation Process
A. Comparison to Preliminary Baseline
B. Assess Qualitative Results
C. Identify and Remove Inhibitors
D. Evaluation Reports

XXXVIII. SPC Case Studies

XXXIX. Exercises
A. Final Project Report

Module #12: Continuing Improvement Strategies

Objectives

1. Identify opportunities for project expansion, improvement area expansion, new project selections and continuous training within their own organization.
2. Discuss the Taguchi concepts of targets and the loss function.
3. Develop and present a strategy for continuing improvement in their own organization.

Content

XL. The Concept of Continuous Improvement

XLI. Identification of Areas for its Application
    A. Inventory
    B. Tooling
    C. Materials
    D. People Etc.
XLII. The Significance of Improve Process Capability
XLIII. Taguchi Loss Function
XLIV. Exercises
    A. Develop Strategy for Continuous Improvement

Quality Improvement / Statistical Process Control Training Program (D. R. Hulse)

Course Outline #2 (QA Inspector and Operator Oriented)

The following is an SPC training program specifically designed to address the needs of QA Inspectors and Machine Operators.

Program Objectives and Strategies

Upon completion of this training program the participant will be able to:

1. Distinguish between detection and prevention mode of operations.
2. List the benefits SPC offers to the manufacturing business.
3. Describe his relationship to the use of SPC in the workplace.
4. Construct an X(bar) and R Chart.
5. Construct a P Chart
6. Construct a nP Chart
7. Construct a c Chart
8. Construct a u Chart
9. Identify Out of Control Conditions.
10. Distinguish between Special and Common Causes.
11. Describe the process of corrective action determination.
12. Describe what is meant by Continuous Improvement.

This training program will be competency based and will adhere to the following format.

1. Competency is described
2. Competency is demonstrated
3. Competency is practiced
4. Competency is performed
5. Competency is evaluated
6. If satisfactory, credit is given
7. If unsatisfactory remedial work is provided
8. Go to 3.

I. Introduction to SPC.
    A. What is Statistical Process Control?
        1. Historical Perspective.
        2. The Nature of the TOOL.
    B. Why use Statistical Process Control?
        1. The Detection Mode of operation
        2. The Prevention Mode of operation
    C. How does Statistical Process Control Work?
        1. Define the product
        2. Define and understand the process
        3. Collect Data
        4. Format the Data

5. Analyze the Data
6. Determine Corrective Action
7. Continuous Improvement

D. What part do you play in making SPC work?
1. Understand your part in the manufacturing process.
a) The Product.
b) The Process.
c) Your job responsibilities.
2. Collect Data.
3. Process Data.
4. Identify Out of Control Conditions.
5. Assist in determining Corrective Action.
6. Assist in taking Corrective Action.

E. What part does the management play in making SPC work?
1. Delegating Responsiblity.
2. Defining the Product.
3. Defining the Process.
4. Determining the Charting.
5. Determining the Corrective Action.
6. Fascilitate implementation of Corrective Action.

II. Preliminaries
A. Arithmetic Review.
B. Use of the Calculator
C. Product Specifications
D. Gathering Data

III. Charting Data
A. Variables Data
1. The X(bar) and R Chart
a) Subgroups
b) X(barbar)
c) Range and R(bar)
2. Control Limits
a) Calculation of
b) Normal Distribution
3. Out control conditions
4. Corrective Action
5. Process Capability

B. Attribute Data
1. The P Chart
a) Definition
(1) Percent Defective
(2) When it is used
b) The Mechanics
(1) Determine Sample Size
(2) Gather Data
(3) Format Data and Plot
(4) Calculate P(bar)
(5) Determine the UCL and LCL
(6) Out of Control Conditions
2. The nP Chart
a) Definition
(1) Number Defective

Quality Improvement / Statistical Process Control Training Program. (David R. Hulse)

The SPC Training Program shall be performance based and criteria referenced. That is, sucessful completion of the program will mean that the participant has demostrated his ability to perform specific tasks to an objective standard of reference. All competencies and standards of performance will be defined prior to program implementation.

SPC Competencies

Example 1.

Given raw data, variables chart, calculator and straight edge the participant will construct an X(bar) and R chart that is free from error in computations and plotting.

Criteria

Subgroup Averages, X(bar), Calculated Correctly.	yes no
X(bar) Plotted Correctly	yes no
Subgroup Range, R, Calculated Correctly.	yes no
R Plotted Correctly	yes no
Process Mean, X(barbar), Calculated Correctly	yes no
X(barbar) Plotted Correctly	yes no
Range Mean, R(bar), Calculated Correctly	yes no
R(bar) Plotted Correctly	yes no
Upper Control Limit, UCL, Calculated Correctly	yes no
UCL Plotted Correctly	yes no
Lower Control Limit, LCL, Calculated Correctly	yes no

Example 2.

Given an complete X(bar) and R chart the participant will identify out of control conditions associated with the process.

Criteria

Lists four out of control conditions	yes no
Identifies points outside of the control limits	yes no

(2) When it is used
b) The Mechanics
(1) Determine Sample Size
(2) Gather Data
(3) Format Data and Plot
(4) Calculate nP(bar)
(5) Determine the UCL and LCL
(6) Out of control conditions

3. The u Chart
a) Definition
(1) Number Defective in a varying lot size
(2) When it is used
b) The Mechanics
(1) Determine the Sample Size
(2) Gather Data
(3) Format Data and Plot
(4) Calculate u(bar)
(5) Determine the UCL and LCL
(6) Out of control conditions

4. The c Chart
a) Definition
(1) Number Defective in a constant lot size
b) The Mechanics
(1) Determine the Sample Size
(2) Gather Data
(3) Format Data and Plot
(4) Calculate c(bar)
(5) Determine the UCL and LCL
(6) Out of control conditions

IV. Summary
A. Practical examples illustrating the total process and its philosohy.

Identifies a run of seven above or below the mean yes no

Identifies an ascending or descending run of seven yes no

Identifies 2 out of 3 points outside 2 sigma yes no

Identifies 4 out of 5 points outside 1 sigma yes no

CRSDEV1/ROTMCHO1: "Rotating Machines Outline 1"
(David R. Hulse)

Note: This outline represents a resource from which program content can be established.

I. Topic Outline
    A. Principles that pertain to the subject
        1. DC Circuit Analysis
        2. AC Circuit Analysis
        3. Three Phase Circuit Analysis
        4. Electromechanical Energy Conversion
            a) Ohm's Law
            b) Kichoff's Voltage Law
            c) Kirchoff's Current Law
            d) Faraday's Law of Induction
            e) Ampere's Magnetic Field Principles
            f) Biot-Sarvat's Force Law
            g) Watt's Power Principle
    B. Devices that pertain to the subject
        1. DC Machines
            a) The Shunt Wound Motor
            b) The Series Wound Motor
            c) The Compound Wound Motor
            d) The Shunt Wound Generator
            e) The Series Wound Generator
            f) The Compound Wound Generator
        2. AC Single Phase Machines
            a) The Split Phase Motor
            b) The Capacitor Start Motor
            c) The Capacitor Run Motor
            d) The Capacitor Start/Capacitor Run Motor
            e) The Universal Motor
            f) The Repulsion Start/Induction Run Motor
        3. AC Three Phase Machines
            a) The Squirrel Cage Induction Motor
            b) The Wound Rotor Motor
            c) The Synchronous Motor
            d) The Three Phase Alternator
    C. Skills that pertain to the subject
        1. Wiring
            a) Schematic Interpretation
            b) Components
                (1) Wire
                (2) Connectors
                (3) Conduit
                (4) Hand Tools
                (5) Small Power Tools
        2. Measurement
            a) Voltmeter
            b) Ammeter
            c) Watt Meter
            d) Oscilloscope
            e) Phase Sequence Meter

f) Phase Angle Meter
g) Tachometer

3. Mechanical Assembly and Disassembly

II. Resources
A. Lab 5
B. Lab Volt Electromechanical Trainer
C. Off the Shelf Components
D. Instrumentation
E. Tools
F. Text

CRSDEV1/MTCNT101/OUTLINE: "Electric Motor Controls Part 1"

I. Topic Outline: Electro-Mechanical Control Systems.
- A. Principles that pertain to the subject.
  1. AC circuit analysis
  2. Single phase circuits
  3. Three phase circuits
  4. Magnetism
  5. Switching Circuits
- B. Devices that pertain to the subject.
  1. Toggle switches
     a) Single pole single throw
     b) Single pole double throw
     c) Double pole single throw
     d) Double pole double throw
  2. Pilot devices
     a) Preasure switches
     b) Float switches
     c) Thermal switches
     d) Flow switches
     e) Limit switches
     f) Pushbuttons
     g) Indicator lights
  3. Relays
     a) Control
     b) Time delay
     c) Overcurrent
     d) Overvoltage
  4. Contactors
     a) Single phase
     b) Three phase
  5. Motor Starters
     a) Manuel
     b) Magnetic
  6. Disconnects
  7. Control Voltage Transformers
- C. AC Motor Control Circuits (single and three phase)
  1. Two way switching circuits
  2. Three way switching circuits
  3. Two wire control
  4. Three wire control
  5. Start-Stop-Jog
  6. Forward-Reverse
  7. Multiple station control
  8. Sequence control
  9. Reduced Voltage Starts
  10. Multispeed control
  11. Braking circuits
     a) Plugging
     b) Dynamic Braking
     c) Mechnical Brakes
- D. DC Motor Control Circuits
  1. Series resistance starts
  2. Counter EMF Controller

3. Voltage Drop Acceleration
4. Magnetic Time Limit Controller
5. Series Relay Acceleration
6. Speed Control Circuits

E. Skills that pertain to the subject
1. Schmatic interpretation
   a) Symbols
   b) Ladder diagram
2. Wiring
   a) Circuit design
      (1) Component selection
      (2) Circuit configuration
   b) Circuit assembly
3. Circuit troubleshooting
4. Circuit repair

CRSDEV1/ELSYO1: Industrial Electrical Systems Outline 1

I. Topic Outline
- A. Principles that pertain to the subject
  - 1. AC circuit analysis
  - 2. Single phase circuit analysis
  - 3. Three phase circuit analysis
    - a) Three phase voltage
    - b) Three phase current
    - c) Three phase loads
      - (1) Balanced
      - (2) Unbalanced
    - d) Three phase power
  - 4. Electromagnetic Induction
  - 5. Principles of Electrical Distribution
    - a) Standards: The National Electrical Code
    - b) Practices
      - (1) Circuit Design
        - (a) Conductor Selection
        - (b) Conduit Selection
        - (c) Overcurrent Protection
        - (d) Grounding
      - (2) Circuit Construction
- B. Devices that pertain the subject
  - 1. Transformers
    - a) Single phase
      - (1) Two wire systems
      - (2) Three wire systems
    - b) Three phase
      - (1) Wye primary - Wye secondary
      - (2) Wye primary - Delta secondary
      - (3) Delta primary - Wye secondary
      - (4) Delta primary - Delta secondary
      - (5) Five wire Wye system
      - (6) Delta with a tapped secondary winding
      - (7) Open Delta
  - 2. Disconnects
    - a) Fused
    - b) Unfused
  - 3. Overcurrent protection devices
    - a) Fuses
    - b) Breakers
    - c) Ground-Fault Interuptors
  - 4. Conductors
  - 5. Conduit and connectors
  - 6. Three phase loads
    - a) Lighting
    - b) Machines
- C. Skills that pertain to the subject
  - 1. Circuit design
    - a) Determination of circuit configuration
    - b) Component selection and sizing
  - 2. Wiring
    - a) Schematic interpretation

b) Conduit bending
c) Conduit hanging
d) Wire pulling
e) Wire termination

3. Measurement
   a) Rule
   b) Plumb bob
4. Hand and power tools
   a) Portable Electric Drill
   b) Hack saw
   c) Linemans pliers
   d) Channel lock pliers
   e) Screw drivers
   f) Conduit bender
   g) wire strippers
   h) hammer

II. Resources
   A. Lab 5 and 6
   B. Lab Volt Electromechanical Trainers
   C. Transformer Trainers
   D. Off the shelf components
   E. Hand and power tools (tool crib)
   F. Text

CRSDEV1/MPTO1: "Mechanical Power Transmission Outline 1"
(David R. Hulse)

I. Topic Outline
    A. Principles that pertain to the subject
        1. Elementry Mechanics
            a) Statics
            b) Dynamics
        2. Mechanisms (Analysis: Kenematics and Energy Transfer)
            a) Belt and Chain Drives
            b) Gear Drives
            c) Worm and Wheel
            d) Block and Screw
            e) Cams
            f) Linkages
            g) Combined Mechanism
    B. Devices that pertain to the subject
        1. Drive Components
            a) Belts and Sheaves
            b) Chains and Sprockets
            c) Gears
            d) Couplings
            e) Bearings and Shafts
        2. Lubricants
        3. Control Devices
            a) Cams
            b) Cam followers
            c) Linkages
        4. Speed Reducers
    C. Skills that pertain to the subject
        1. Assembly and Disassembly
            a) Blue Print Interpretation
            b) Components
                (1) Fasteners
                (2) Shimming Materials
                (3) Hand Tools
                (4) Power Tools
            c) Procedures
                (1) Tool selection
                (2) Allignment
                (3) Tensioning
        2. Measurement
            a) The Rule
            b) The Micrometer
            c) The Vernier Caliper
            d) The Tachometer
            e) The Torque Wrench
II. Resources
    A. Lab 8
    B. Mechanical Systems Trainer (4)
    C. Mechanisms Trainer (5)
    D. Off the Shelf Components
    E. Measurement Tools

F. Hand and Power Tools
G. Text

CRSDEV1/FPO1: "Fluid Power Outline 1"

I. Topic Outline
- A. Principles that pertain to the subject
  - 1. Elementary Mechanics
    - a) Mass
    - b) Force
    - c) Preasure
    - d) Velocity
    - e) Acceleration
    - f) Work
    - g) Mechanical Advantage
  - 2. Fluid Mechanics
    - a) Density
    - b) Viscosity
    - c) Viscosity Index
    - d) Specific Gravity
    - e) Humidity
    - f) Pascal's Law
    - g) Bernoulli's Theorem
    - h) Energy Conversion (Mechanical/Hydraulic)
- B. Devices that pertain to the subject
  - 1. Energy Converting Devices
    - a) Pumps
    - b) Compressors
    - c) Motors
    - d) Cylinders
  - 2. Control Devices
    - a) Pressure Control Valves
    - b) Flow Control Valves
    - c) Directional Control Valves
    - d) Pilot Devices
  - 3. Plumbing Components
    - a) Connectors
    - b) Piping
    - c) Tubing
    - d) Hoses
  - 4. Instrumentation
    - a) Pressure Gauges
    - b) Flow Meters
    - c) Level Indicators
    - d) Temperature Indicators
  - 5. Accessories
    - a) Reserviors
    - b) Accumulators
    - c) Filters
    - d) Strainers
    - e) Heat Exchangers
- C. Basic circuit functions
  - 1. Directional Control Circuits
  - 2. Pressure Control Circuits
  - 3. Flow Control Circuits
  - 4. Energy Storage Circuits
- D. Servo Systems

1. Input Transducers
2. Signal Conditioners
3. Controllers
4. Final Control Elements
5. Circuits

E. Skills that pertain to the subject
1. Plumbing
a) Schematic Interpretation
b) Circuit Fabrication Techniques
a) Hand Tools
b) Piping
c) Tubing
d) Hoses
2. Assembly and Disassembly
a) Blue Print Interpretation
b) Tool Selection and Use
c) Allignment
d) Tensioning
3. Measurement
a) Pressure
b) Flow Rate
c) Temperature
d) Fluid Contamination
4. Trouble Shooting

II. Resources
A. Lab 7
B. Digiac Fluid Power Trainer (1)
C. Lab Volt Fluid Power Trainer (1)
D. Hickok Fluid Power Trainer (1)
E. PVT Fluid Power Trainer (2)
F. Off the Shelf Components
G. Tools
H. Instrumentation
I. Text